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Report No. 3222

HEARING CONSERVATION PROGRAM PROTOTYPE PHASE FINAL REPORT

J. Lehr
D. Nelson
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September 1976

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This report covers the prototype phase of an OPNAV sponsored hearing conservation program. The objective of the prototype phase was to demonstrate the feasibility of reducing machinery space noise levels sufficiently to comply with BUMED/OSHA hearing damage risk criteria.

The USS ELMER MONTGOMERY (FF 1082), the designated prototype ship, was subjected to comprehensive underway and dockside diagnostic noise testing. The tests indicated that even at nominal 15 to 20 knot cruising

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) speeds, noise levels at many manned locations in the engine room and fire room exceeded the BUMED 90 dBA hearing damage risk criterion. Diagnostic tests determined that while several sources contributed to the high noise levels, the noise environment was dominated by the main reduction gear in the engine room and by noise radiated from forced draft blower ducts and ventilation exhaust fans in the fire room. These dominate sources were approved for treatment in the prototype program. Noise levels at manned locations in auxiliary machinery spaces were found to be acceptable under normal operating conditions.

Conceptual approaches for noise control treatment were provided to the naval shipyard which developed the design for the prototype treatments. The treatments were installed during a scheduled restricted availability. The shipyard costs associated with this prototype installation were $233K.

Subsequent noise trials conducted to assess the performance of the prototype treatments indicated the predicted noise reduction from the treatments was achieved. Noise levels at all machinery space manned locations remained below the BUMED 90 dBA criterion at all speeds up to 23 knots, and through 26 knots in the engine room. The prototype treatments were, therefore, judged successful.

Noise trials were also conducted on a second ship in the class, the USS DOWNES (FF 1070), to insure that differences in equipment manufacture or shipyard construction practices did not result in significant differences in the noise environment within the FF 1052 class machinery spaces. Only minor variations in the noise environment were found, but were not significant enough to argue against a single set of noise control treatments for the entire FF 1052 class of ships.

The report concludes with a recommended noise control package for ships of the FF 1052 class. In addition to the prototype treatments installed in ELMER MONTGOMERY for the main reduction gear, forced draft blower ducts and fire room exhaust fans, the recommended noise control package recommends silencers for fire pump motors in the engine and fire rooms and rerouting of the Prairie/Masker vent in ships where the vent is currently terminated in the fire room. The estimated cost of this package is $200K per ship in 1976 dollars.

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EXECUTIVE SUMMARY

This report covers the prototype phase of an OPNAV sponsored hearing conservation program aimed at reducing hazardous airborne noise levels in the machinery spaces of surface ships. The prototype phase was concerned with a feasibility assessment of prototype noise treatment installation in a ship of the FF 1052 class and the identification of potential differences in noise characteristics in ships within the class. (There are differences in machinery manufacturers between the older ships and FF 1078 and later ships in the class.) USS ELMER MONTGOMERY (FF 1082) received the prototype installation, and USS DOWNES (FF 1070) was tested to identify potential differences in noise characteristics.

Extensive diagnostic airborne noise testing was conducted underway and dockside in the machinery spaces in USS ELMER MONTGOMERY (FF 1082) in March 1975. These tests indicated that at nominal operating speeds (15 to 20 knots) noise levels at many of the manned locations in the engine room and fire room exceeded the BUMED/OSHA 90 dBA hearing damage risk criteria. This condition improved only slightly at lower speeds, and at higher speeds the 90 dBA criterion was exceeded at all measurement locations. In auxiliary machinery spaces, the noise levels were essentially independent of speed and did not exceed the 90 dBA criterion.

Diagnostic tests were used to identify and classify individual noise sources. The dominant noise source in the engine room was the main reduction gear. Distiller brine overboard eductors and the motor-driven fire pump were also significant noise sources contributing to the excessive noise levels. In the fire room, forced draft blower duct radiation and ventilation exhaust fans were the dominant sources. The vent exhaust fans exceeded the 90 dBA criterion when operated alone at dockside. The fire pump in the fire room was also a significant noise source. An extremely hazardous transient noise problem was also noted, as air from the Prairie/Masker compressors vented directly into the fire room during warmup. Noise levels as high as 125 dBA were measured during the thirty to sixty minute compressor warmup period. Noise levels as high as 118 dBA were measured with the compressors feeding the masker belts. It was not clear whether this was a class problem, or one peculiar to ELMER MONTGOMERY: however, later tests showed that a properly functioning Prairie/Masker system should not vent inboard under normal operating conditions (i.e., after compressor warmup) and consequently would not present a noise problem if inboard venting did not occur.

The proposed prototype noise control installation in ELMER MONTGOMERY included a close-coupled treatment for the main reduction gear casing and associated foundation, acoustical lagging of forced draft blower ducts and brine overboard eductors, silencer devices for fire room ventilation exhaust fans and rerouting of the vents for the Prairie/Masker compressors to the uptake space. The proposed treatments were installed during a restricted availability (RAV), except for the brine overboard eductors. (A SHIPALT is already developed and scheduled to replace the eductors with quiet pumps.) In addition to the prototype installation work, the shipyard developed a design for running the vents for the Prairie/Masker compressors out of the fire room into the uptake space; however, the installation work was not accomplished. Shipyard costs associated with the prototype installation were $233K.

Post-RAV noise trials conducted to evaluate the prototype installation showed that the treatment performed essentially as predicted. Noise levels at all manned locations in the machinery spaces were below the BUMED hearing damage risk criteria at all speeds up to 23 knots (and through 26 knots in the engine room). These reductions have increased the allowable personnel exposure time at 20 knots without hearing protection from two hours to nine hours in the fire room and from four hours to nine hours in the engine room. The post-RAV tests indicate that the prototype installation is a feasible approach to reducing hazardous noise levels in the machinery spaces of FF 1052 class ships.

In January 1976, airborne noise trials were conducted in the machinery spaces in USS DOWNES (FF 1070). The DOWNES was constructed in a different shipyard than ELMER MONTGOMERY and was equipped with main reduction gear and boilers from different manufacturers. No other significant differences in machinery were identified; however, the forced draft blower ducts on DOWNES had been lagged with thermal lagging material. The purpose of the DOWNES trials was to determine if there were significant differences in the noise environment due to differences in machinery components or construction practices.

In the engine room the noise levels in DOWNES were slightly lower than in ELMER MONTGOMERY, and dominant tones from the main reduction gear were found at different frequencies due to differences in gear design. In the fire room, the only significant difference found was associated with the Prairie/ Masker compressors. The vents on the DOWNES compressors were routed out of the fire room to the uptake space and consequently produced no noise problem. The DOWNES trial indicates that the noise problems and associated solutions should be common throughout the FF 1052 class.

Concurrent with the ELMER MONTGOMERY prototype installation, noise control treatment was being applied to quiet the main reduction gears in USS SOUTH CAROLINA (CGN 37). This installation was an acoustical enclosure rather than the close-coupled treatment applied directly to the gear casing in ELMER MONTGOMERY. Subsequent tests of SOUTH CAROLINA showed that the enclosure also represents a feasible approach to control of main reduction gear noise, and thus provides a practical alternative where arrangements permit use of an enclosure.

On the basis of the evaluation of the prototype installation in ELMER MONTGOMERY and tests conducted aboard USS DOWNES, recommendations for noise control treatment for machinery spaces of ships in the FF 1052 class have been developed and are provided below. The prototype treatments installed in ELMER MONTGOMERY are described in Section II. B and C.

1. The main reduction gear, its foundation and the foundations and subbases for the main turbines should be treated with the type of close-coupled treatment installed in USS ELMER MONTGOMERY or enclosed in a manner similar to the installation in USS SOUTH CAROLINA. The reduction gear lube oil piping should be either lagged or enclosed.

2. The forced draft blower ducts should be acoustically lagged as was done on ELMER MONTGOMERY.

3. Both fire room exhaust fans should be relocated in the uptake space and reconnected to existing bellmouths, using acoustically lined ducts including 90 degree elbows as was done on the larger exhaust fan in ELMER MONTGOMERY.

4. The fire pump motors in the engine room and fire rooms should be provided with motor silencers.

5. In those ships where the Prairie/Masker vent currently terminates in the fire room, it should be extended into the uptake space.

The estimated cost of these recommended noise control treatments is approximately $200K per ship in 1976 dollars. This estimate does not include the cost of the SHIPALT to replace the brine overboard eductors which is already scheduled.

I. INTRODUCTION AND BACKGROUND

As an initial step in the program, it was determined necessary to demonstrate that by using current machinery noise reduction technology, shipboard machinery room noise levels could be reduced below hearing damage risk levels without a costly development program. A frigate of FF 1052 class was selected for the prototype installation because of the large number of recently constructed ships in the class, and because the single fire room and engine room helped to keep the cost down.

After an exchange of correspondence to define the scope of the prototype program, the CNO approved the concept of a prototype machinery space noise reduction installation in one ship of FF 1052 class by reference (10). To reduce the time and cost of the prototype program, reference (11) submitted a revised plan of action which limited the scope of the treatment to the known major noise offenders in the machinery spaces, the main reduction gear and the forced draft blowers. By limiting the scope and installing noise reduction treatments during a restricted availability rather than a regular overhaul, the overall time required to demonstrate the feasibility of achieving the BUMED hearing damage avoidance criteria in FF 1052 class main machinery spaces was reduced from two years to one year.

The approved plan also included a noise trial in another ship of the FF 1052 class to determine if differences in machinery within the class results in significant differences in airborne noise characteristics. Trials of the second ship were also designed to minimize the possibility that the ship receiving the prototype installation might be exceptionally noisy or quiet compared with other ships of the class.

This report covers the first or prototype phase of the Hearing Conservation Program which has been completed. The report describes: the noise trials which were conducted and the results of trial data analysis; the noise reduction treatments which were installed in the prototype ship; prediction of noise treatment performance based on laboratory tests; the assessment of the noise reduction achieved from the installed treatments; the differences between ships within the FF 1052 class and the significance thereof; and conclusions reached from the prototype installation. Finally, the report provides recommendations for FF 1052 class improvements which will be required to achieve OSHA/BUMED hearing damage risk criteria. Recommendations are also provided for the inclusion of other ship classes in the Hearing Conservation Program. The appendix provides a detailed summary of the data which supports the conclusions and recommendations.

II. PROTOTYPE SHIP

COMNAVSURFLANT designated USS ELMER MONTGOMERY (FF 1082) as the ship to receive the prototype noise reduction treatment. A restricted availability, for LAMPS installation, was scheduled for 7 July to 28 November during which time the noise reduction treatment would be installed.

A. Problem Identification Trial

Enroute to Norfolk from deployment, comprehensive diagnostic airborne noise and vibration tests were conducted in the machinery spaces in USS ELMER MONTGOMERY. The purposes of these tests were to determine baseline noise levels against which noise reduction could be subsequently assessed as well as to determine the contributions of individual noise sources to the overall noise environment as a means of establishing a predictable limit on noise reduction as a function of the noise sources treated.

The results of this noise trial have been reported in detail in a previous report, reference (1). The conclusions drawn from the test data are summarized below. These conclusions include an assessment of the measured noise levels as they relate to the hearing damage risk criterion established by BUMED and OSHA (reference 4 and 5). The BUMED/OSHA criterion establishes maximum allowable noise levels as a function of the duration of exposure. The basic criterion allows an exposure of up to eight hours in a twenty-four hour period to a noise level of 90 dBA.

1.0 Engine Room

The noise levels at various locations in the engine room expressed in single number dBA values at various ship speeds (i.e., shaft RPM) are shown in Table 1. The noise data summarized in Table 1 show that for ship speeds above 100 RPM, approximately 13 knots, only one of the measurement locations is below 90 dBA. At 160 RPM, approximately 21 knots, the 90 dBA level was exceeded at all measurement locations, with a noise in excess of 100 dBA at one location. The data in Table 1 show a definite relationship between noise level and ship speed at all measurement locations indicating that propulsion noise, as opposed to noise produced by auxiliary machinery, is either dominating or strongly influencing the noise levels at all measurement locations.

For a more detailed analysis of the noise levels and the noise sources, five measurement locations were selected as representative of locations where personnel exposure to hazardous noise levels would occur. It was determined from the data that the influence of propulsion noise was clearly established at a ship speed of 160 shaft RPM, thus allowing detailed analytical measurements to be made underway at a reasonable cruising speed. The five measurement locations selected were as follows:

1. Microphone No. 1, located above the workbench on the upper level, port side near air conditioning compressor No. 2.

2. Microphone No. 2, located on the upper level at the watch station between the evaporators.

3. Microphone No. 3, located on the lower level, starboard, aft, near the lube oil purifier.

TABLE 1

USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS
ENGINE ROOM NOISE LEVELS IN dBA
(WITHOUT TREATMENT)

MEASUREMENT LOCATION	MIKE No.	SHIP SPEED IN SHAFT RPM							
		80	100	120	140	160	180	200	220
*ML - Workbench by A/C Plant #2	1	85	87	89	83	92	92	94	97
*ML - Log Desk by Evaps.	2	90	91	91	91	92	93	93	100
LL - Starboard - Outboard MRG	3	96	95	97	95	101	100	102	107
ML - Port - Outboard MRG	5		91			97			
LL - Port - Outboard MRG	7A								
LL - Fwd - Betwn Fire P. & Cond. P.	12					98	98	99	
LL - Fwd - Betwn Cond & Circ Pump	13	95	94	95	94	97	99	99	104
UL - Center of MRG	14					94		97	
ML - Fwd - By Main Air Ejector	17	91	92	91	90	93	93	94	100

LL - Lower Level ML - Middle Level UL - Upper Level

*Manned Locations

4. Microphone No. 13, located on the lower level on the centerline between the condensate pump and the main circulating pump adjacent to the athwartships walkway.

5. Microphone No. 17, located on the upper level on the centerline near the main air ejector and adjacent to the athwartships walkway.

One-third octave band noise levels at the five locations are shown in Figures 1 through 5. Each figure shows two sets of noise levels. The lower set on each figure represents the composite noise level at each location of auxiliary (non-propulsion) machinery as measured dockside, and represents the non-propulsion noise baseline. The upper set shows the noise level measured underway at 160 shaft RPM and represents the total underway noise environment including the contribution of propulsion noise at each location. The equivalent A-weighted levels are shown on the scale at the right side of each figure. From the figures it can be seen that the propulsion noise is concentrated in the 500 through 2500 hertz bands. (It should be noted that A-weighted measurements are influenced most heavily by noise at frequencies above 500 hertz.)

As can be seen from Figures 1 through 5, the propulsion noise is characterized by three distinct peaks. These peaks are caused by tones generated in the main reduction gear. The tone in the 500 hertz band is attributed to the attached lube oil pump gear mesh, the tone in the 800 hertz band is the second reduction gear mesh (bull gear mesh), and the tone in the 2500 hertz band is attributed to undulations in the first reduction gear.

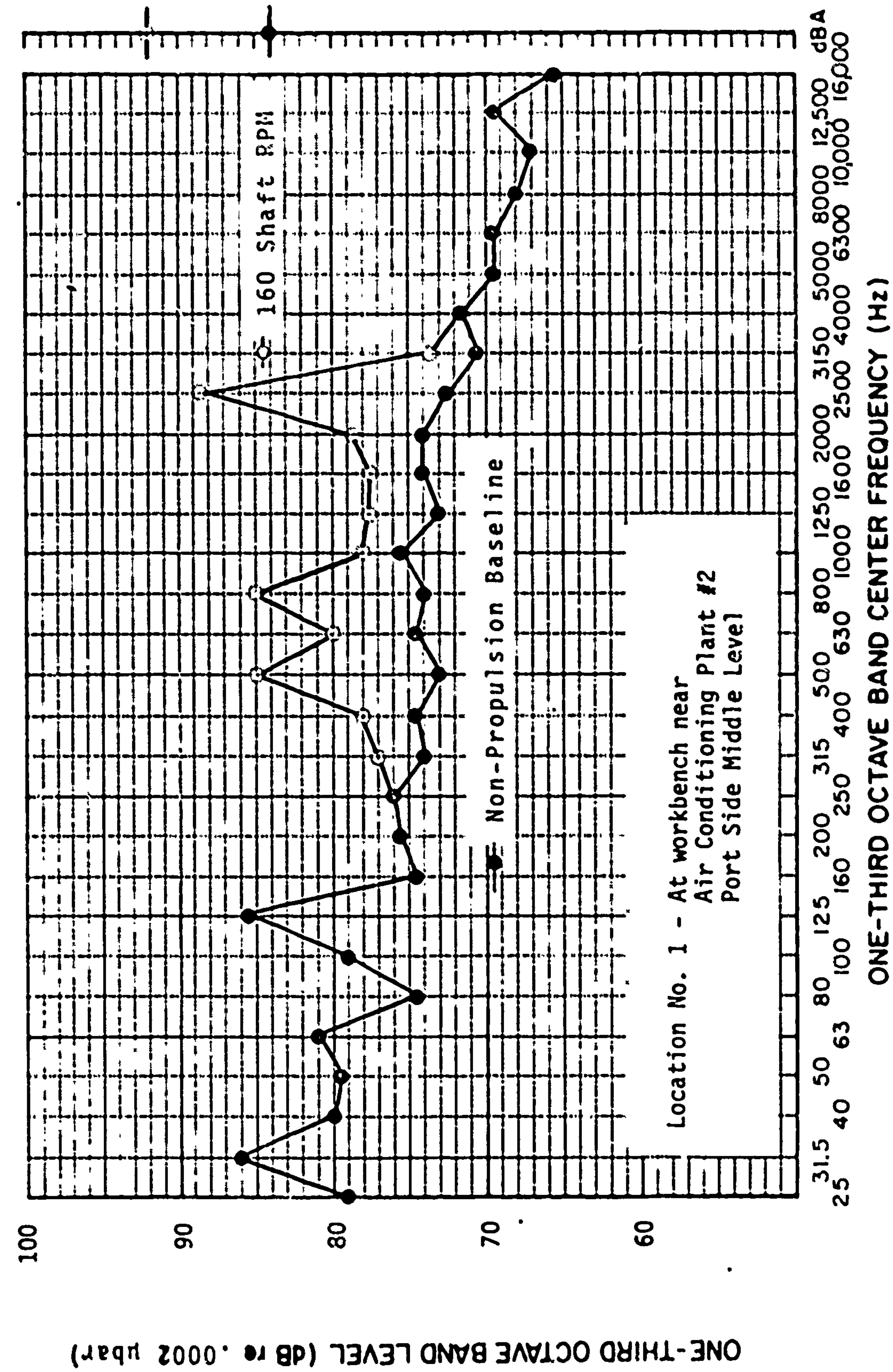


FIGURE 1: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 1 IN ENGINE ROOM

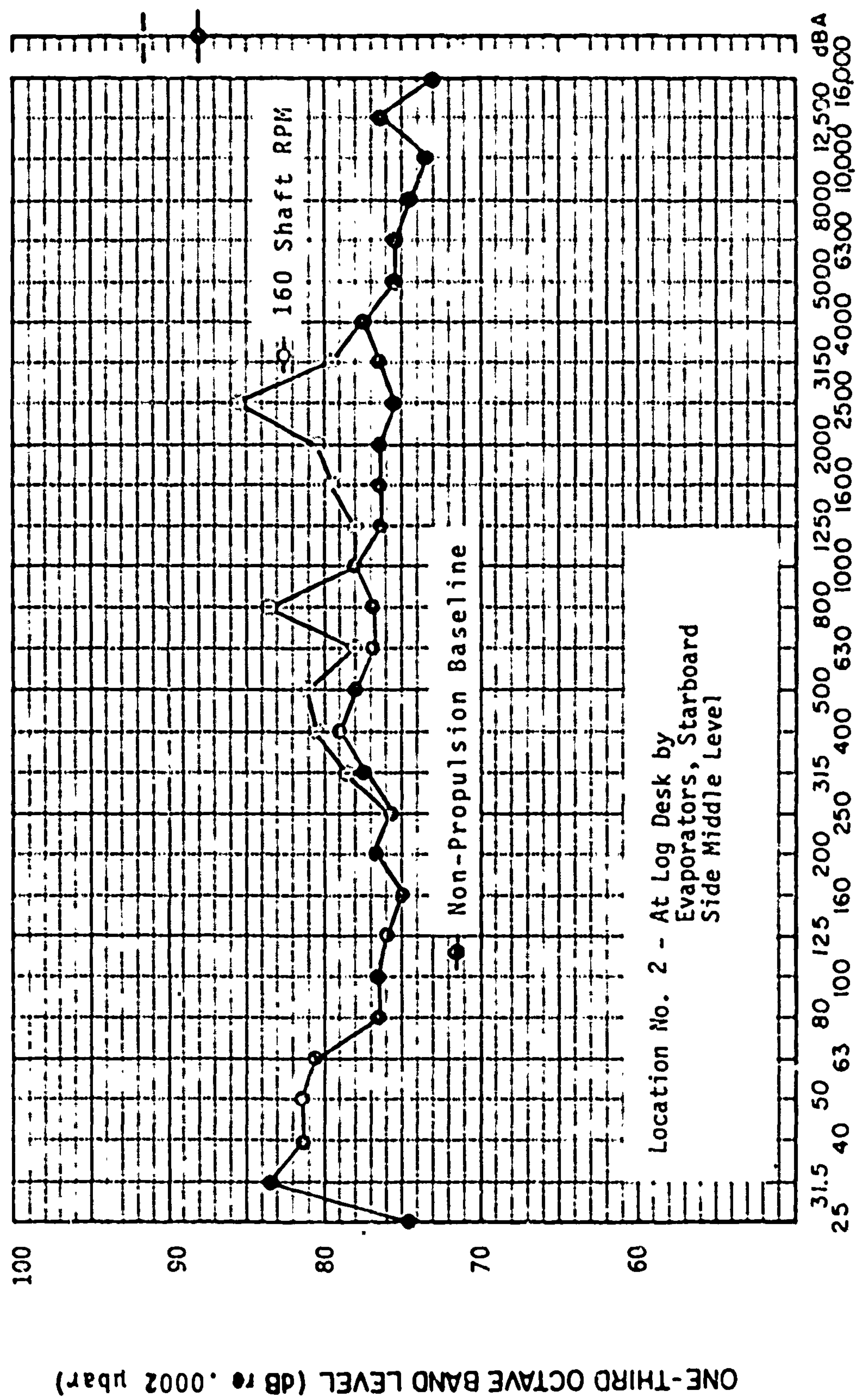


FIGURE 2: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 2 IN ENGINE ROOM

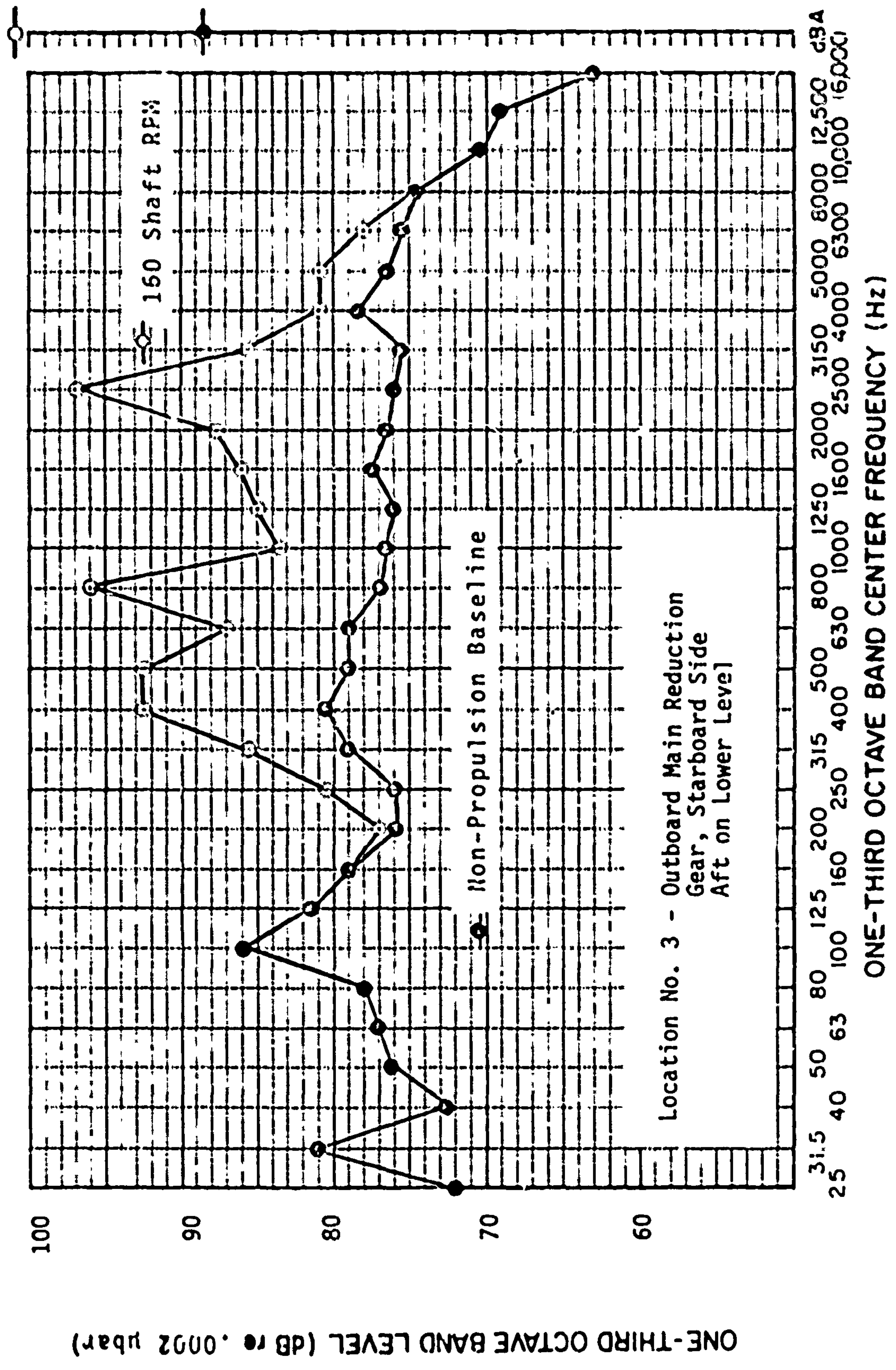


FIGURE 3: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 3 IN ENGINE ROOM

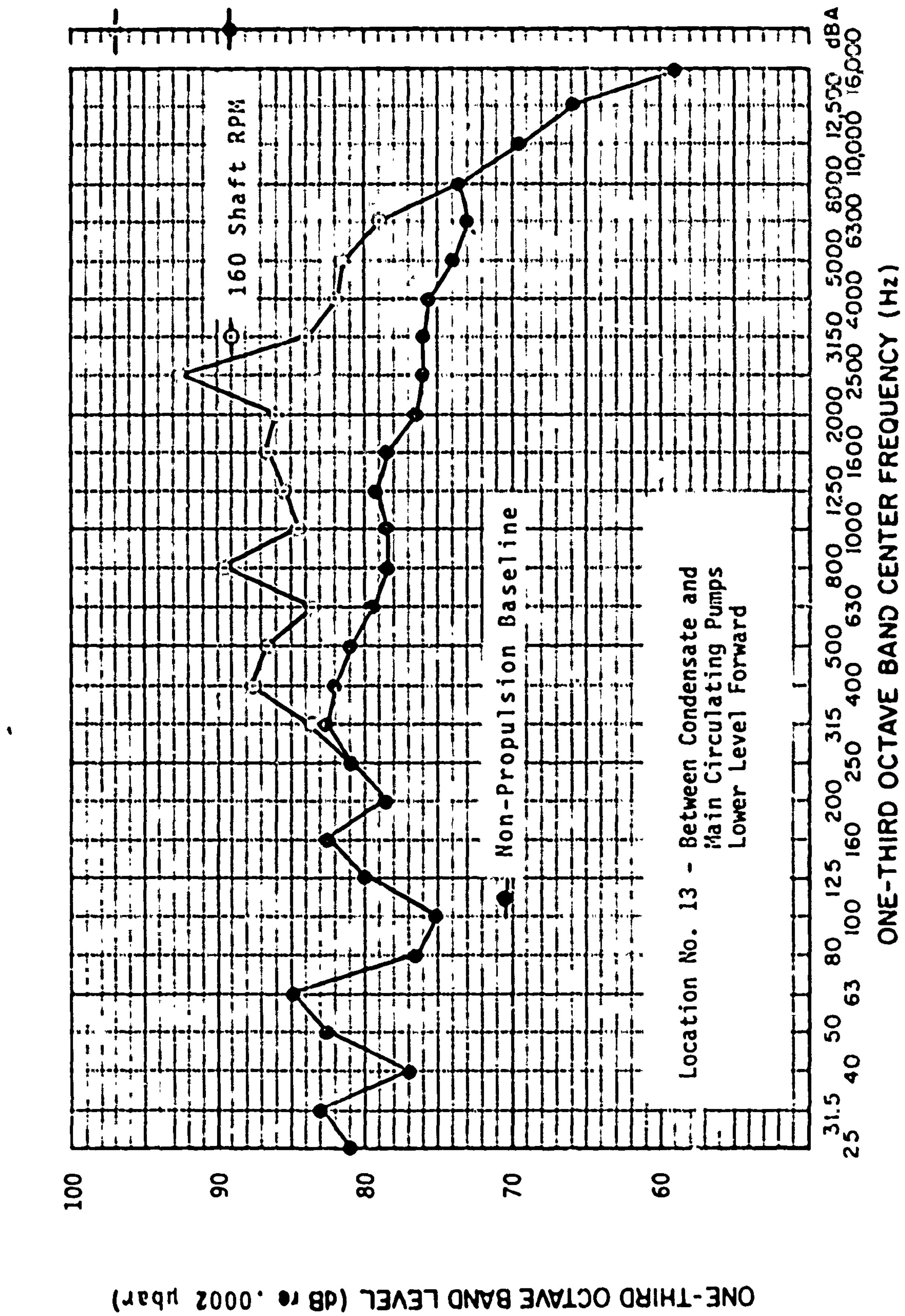


FIGURE 4: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 13 IN ENGINE ROOM

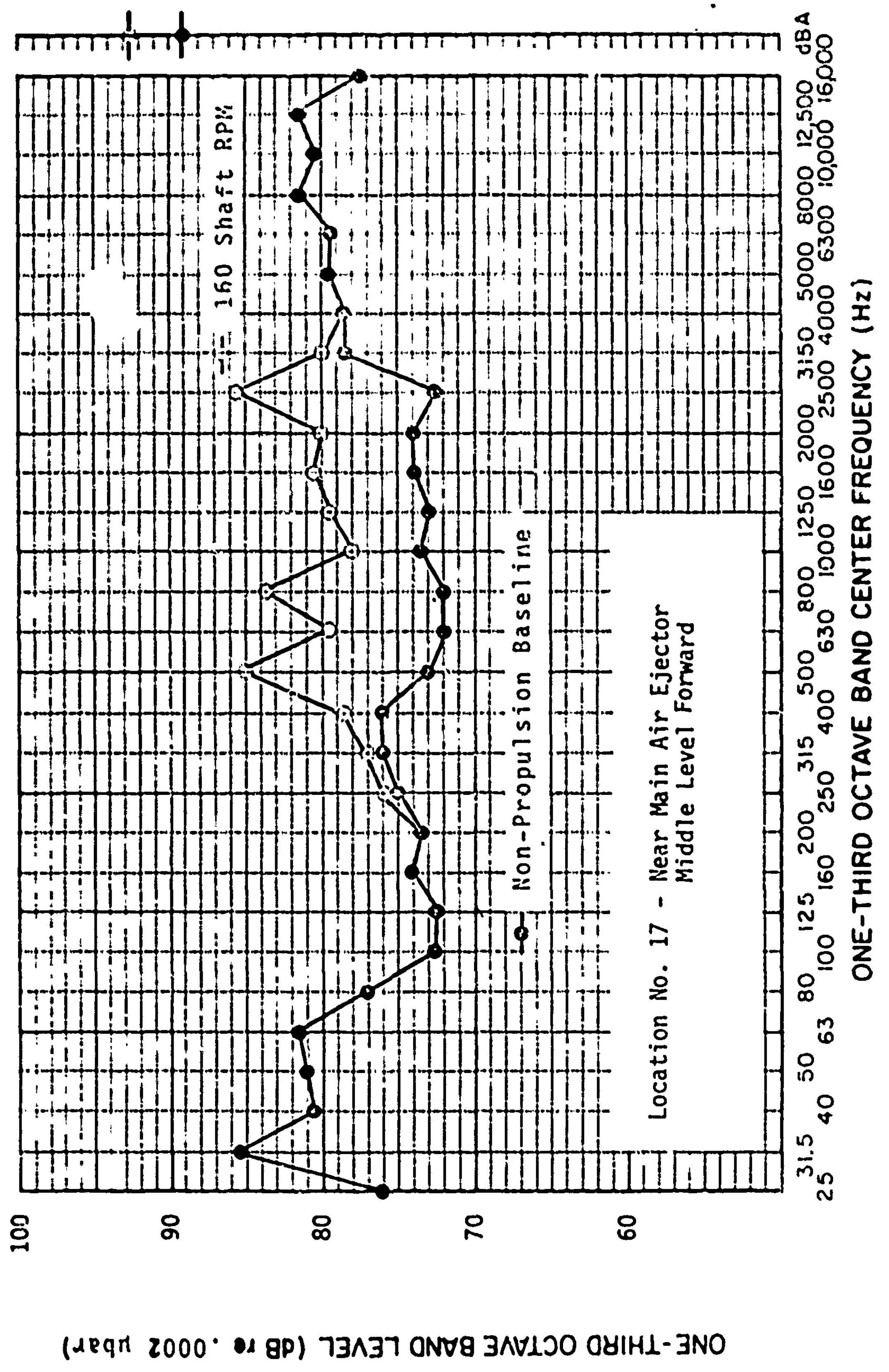


FIGURE 5: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 17 IN ENGINE ROOM

By referring to the equivalent dBA levels displayed on the right side of the figures, the relative influence of propulsion noise at these locations can be deduced by noting the increase in the A-weighted level from the non-propulsion baseline A-weighted level. This difference in the dBA level also represents the maximum noise reduction which can be achieved by reducing only the propulsion noise.

The data from Figures 1 through 5 suggest that if it is feasible to reduce propulsion noise sufficiently, 90 dBA can be achieved at all five locations since the non-propulsion baseline noise levels are below 90 dBA. Such feasibility seems reasonable at measurement locations 1 and 2; however, at the other locations it does not appear feasible to achieve the 90 dBA level by reduction of propulsion noise only. At measurement location No. 3, the non-propulsion baseline level is 89 dBA which means that noise reduction in excess of 25 dB would be required to completely eliminate the influence of propulsion noise. Accomplishment of such reduction is very improbable in a backfit. A similar condition exists at measurement location No. 13, and to a lesser degree at location No. 17. It is necessary, therefore, to reduce auxiliary machinery noise in conjunction with reduction of propulsion noise to achieve 90 dBA at measurement locations 3, 13 and 17.

Results of diagnostic tests conducted dockside with individual auxiliaries operating alone provided insight into the sources of the non-propulsion baseline noise. From these tests it was determined that the non-propulsion baseline noise level at measurement location No. 3 is dominated by noise generated by the distilling plants, primarily the brine overboard eductors and their associated discharge piping. The non-propulsion baseline at measurement location No. 13 is the result of nearly equal contributions from fire pump No. 3 and the main condensate pumps. At measurement location No. 17, the non-propulsion baseline is governed primarily by the main air ejector, particularly at higher frequencies.

2.0 Fire Room

Table 2 shows the measured noise levels at various locations in the fire room expressed in single number dBA values as a function of ships speed expressed in shaft RPM. (NOTE: The data at 80, 100, 120, 140 and 220 RPM were taken with hand-held instruments. There was insufficient time available to repeat these measurements after the fixed instrumentation was transferred from the engine room to the fire room; therefore, the 160, 180 and 200 RPM data is considered more reliable since these runs were repeated with the fixed instrumentation system.) As was the case in the engine room, the noise levels at every measurement location show a speed dependence. This relationship is clearly established upon reaching a speed of 160 RPM, by which time the noise levels at all but three of the locations have exceeded the [illegible] dBA criteria.

The most significant change in machinery condition as a function of speed occurs with the changing demand on the forced draft blowers (i.e., blower speed increases with increases in ship speed). Therefore, the generally higher noise levels on the upper and second deck levels tend to reflect the dominance of forced draft blower noise because of the proximity of the forced draft blower ducts. The noise levels at locations on the lower level of the fire room tend to be lower because they are further removed from the forced draft blower ducts and are dominated by sources having less speed dependence.

TABLE 2

USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS
FIRE ROOM NOISE LEVELS IN dBA
(WITHOUT TREATMENT)

MEASUREMENT LOCATION	MIKE No.	SHIP SPEED IN SHAFT RPM							
		80	100	120	140	160	180	200	220
*LL - At Burner Clng Bench	58	84	84	85	85	86	87	91	91
*LL - Between Boilers Starboard Side	81A	88	88	88	88	90	93	95	97
LL - Near P/M Comp. #1B	82	87	87	87	87	88	90	92	93
UL - Near Main Feed Pump #1C	88	92	91	93	92	94	95	100	102
LL - Near Fire Pump #2	104	88	88	88	88	94	92	94	92
*UL - At Workbench Port Side	155	86	87	87	87	98	93	98	96
UL - Between Ladders Port Fwd	156	85	86	87	86	94	92	97	94
UL - Between Boilers on Centerline	157	91	92	92	92	99	100	102	98
UL - Near Main Feed Pumps #1A &1B	158	86	87	87	87	90	93	96	94
2D - Between Boilers on Centerline	201	95	95	96	97	98	100	103	101
2D - At ladder to FD Blr Room	202	87	89	89	90	97	94	100	97

LL - Lower Level UL - Upper Level 2D - 2nd Deck Level
*Manned Location

Five representative locations have been selected for more detailed analysis. One-third octave band levels taken at these locations at 180 shaft RPM are shown in Figures 6 through 10. The five locations are described as follows:

a. Microphone No. 81A, was located on the lower level, starboard of the centerline between the boilers.

b. Microphone No. 104, located on the lower level, aft port corner, near fire pump No. 2.

c. Microphone No. 155, located on the upper deck, aft port corner, over the workbench adjacent to the control station.

d. Microphone No. 157, located on the upper level, on the centerline between the boilers.

e. Microphone No. 201, located on the second deck level, on the centerline between the boilers.

These locations were considered representative of those frequently or continuously manned stations.

Dockside cycling of machinery in the fire room was somewhat limited in that steam driven machinery could not be measured independently. However, cycling of motor driven auxiliaries demonstrated that the ventilation system was a significant contributor to the overall noise levels at some locations. Therefore, the noise levels of the vent system at the five measurement locations are shown as the lower set of values on Figures 6 through 10. Referring to Figure 10, it can be seen that the vent system, operating alone, produces

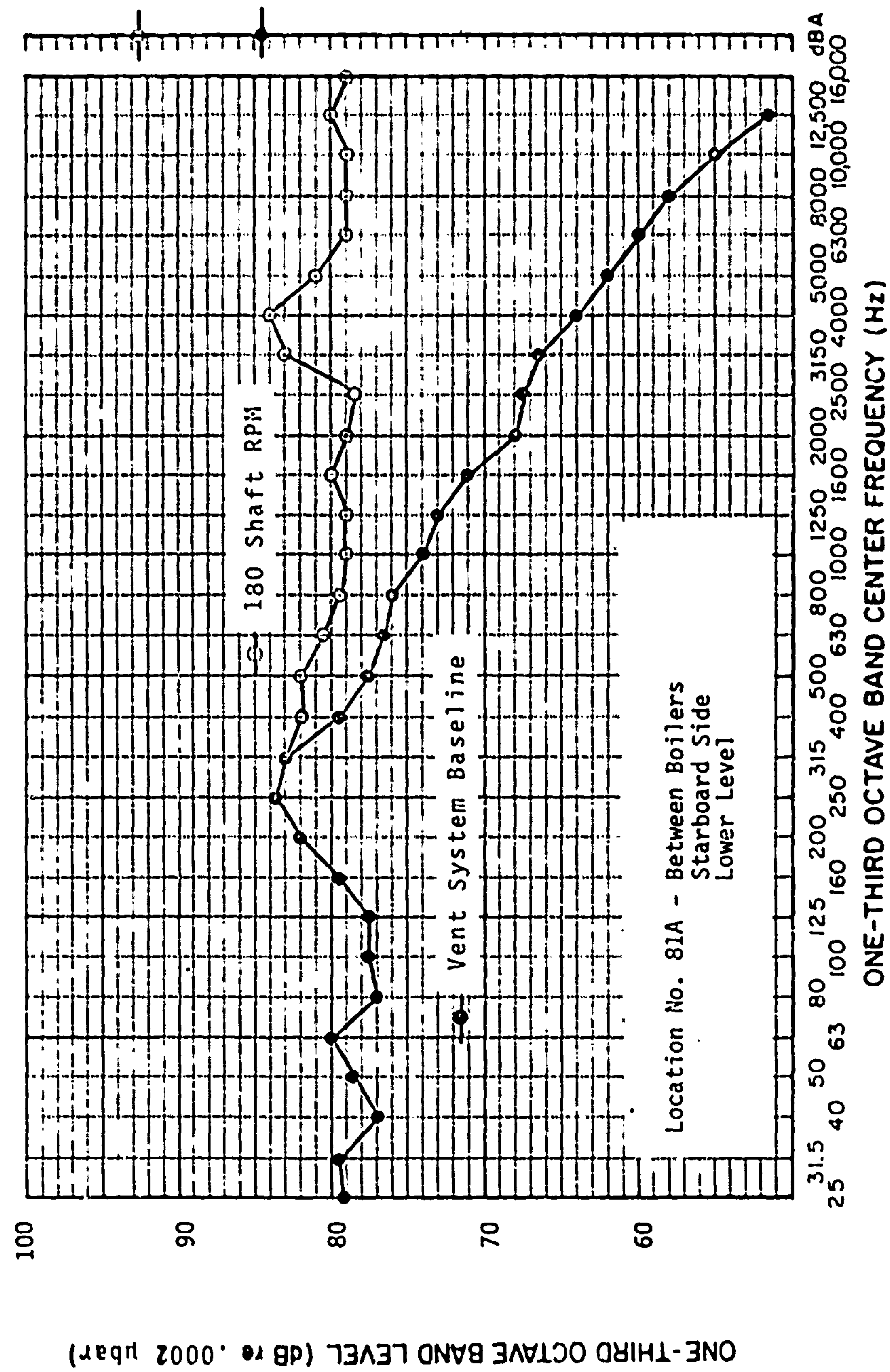


FIGURE 6: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 81A IN THE FIRE ROOM

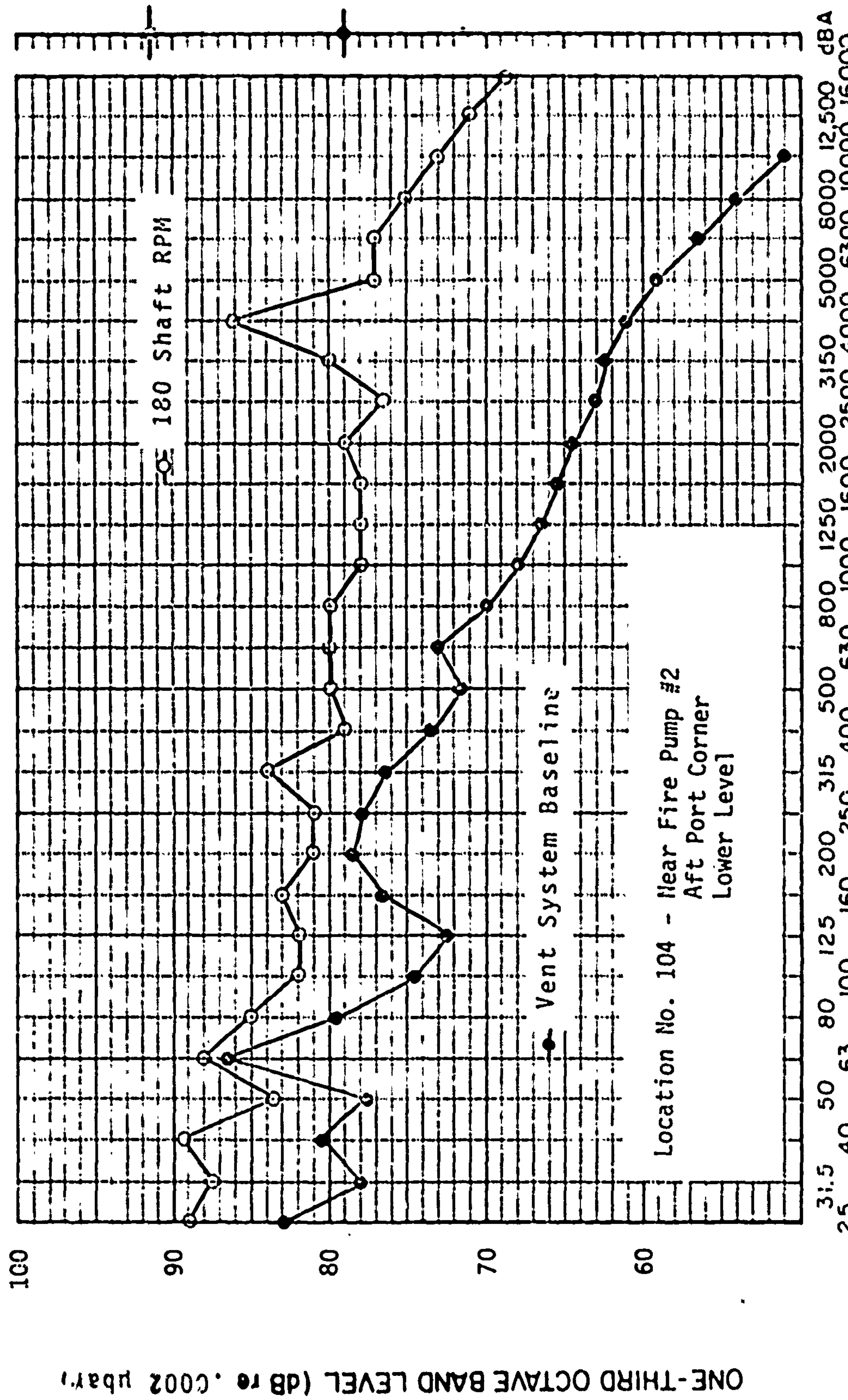


FIGURE 7: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT
LOCATION NO. 104 IN FIRE ROOM

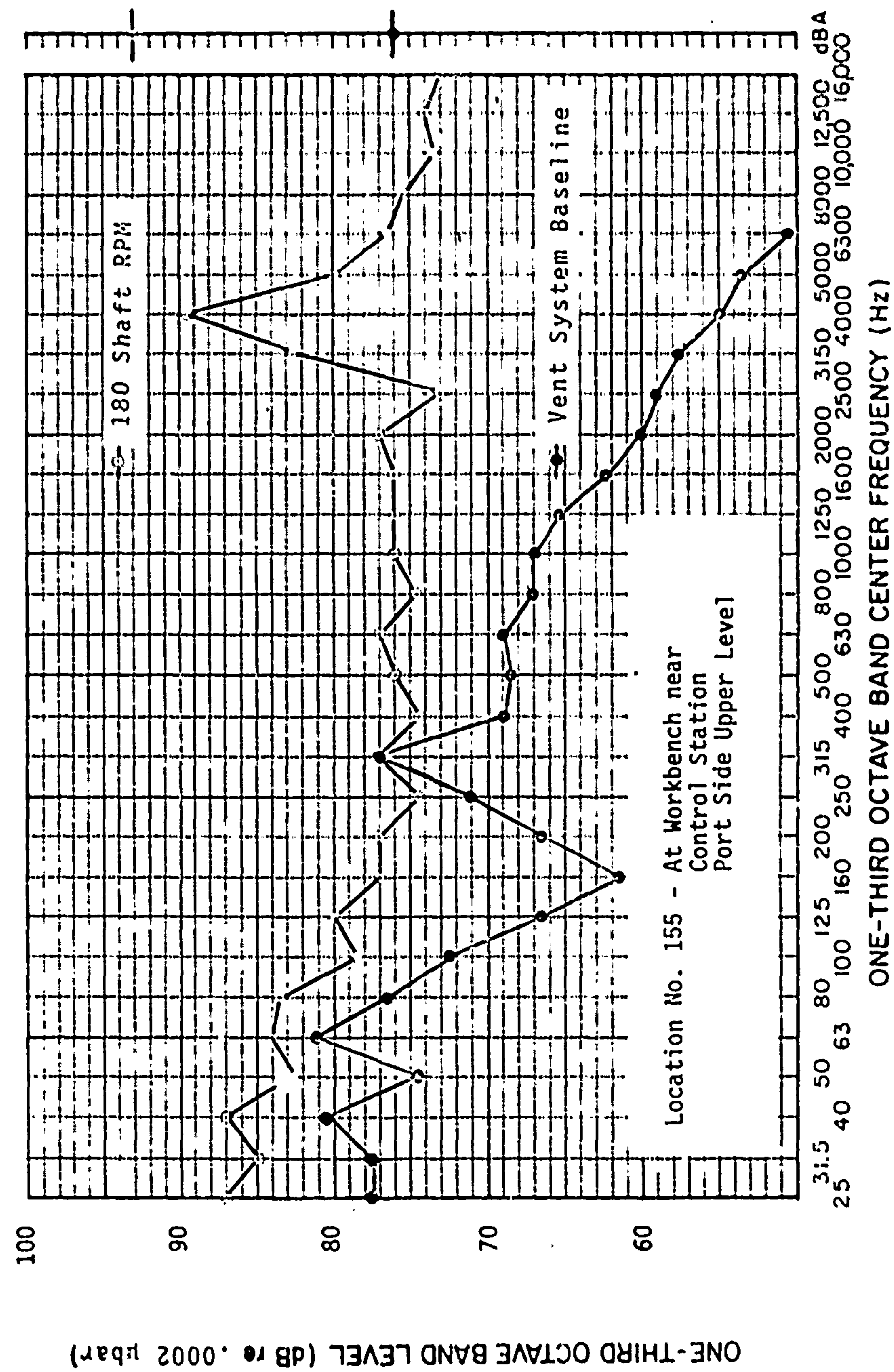


FIGURE 8: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT
LOCATION NO. 155 IN FIRE ROOM

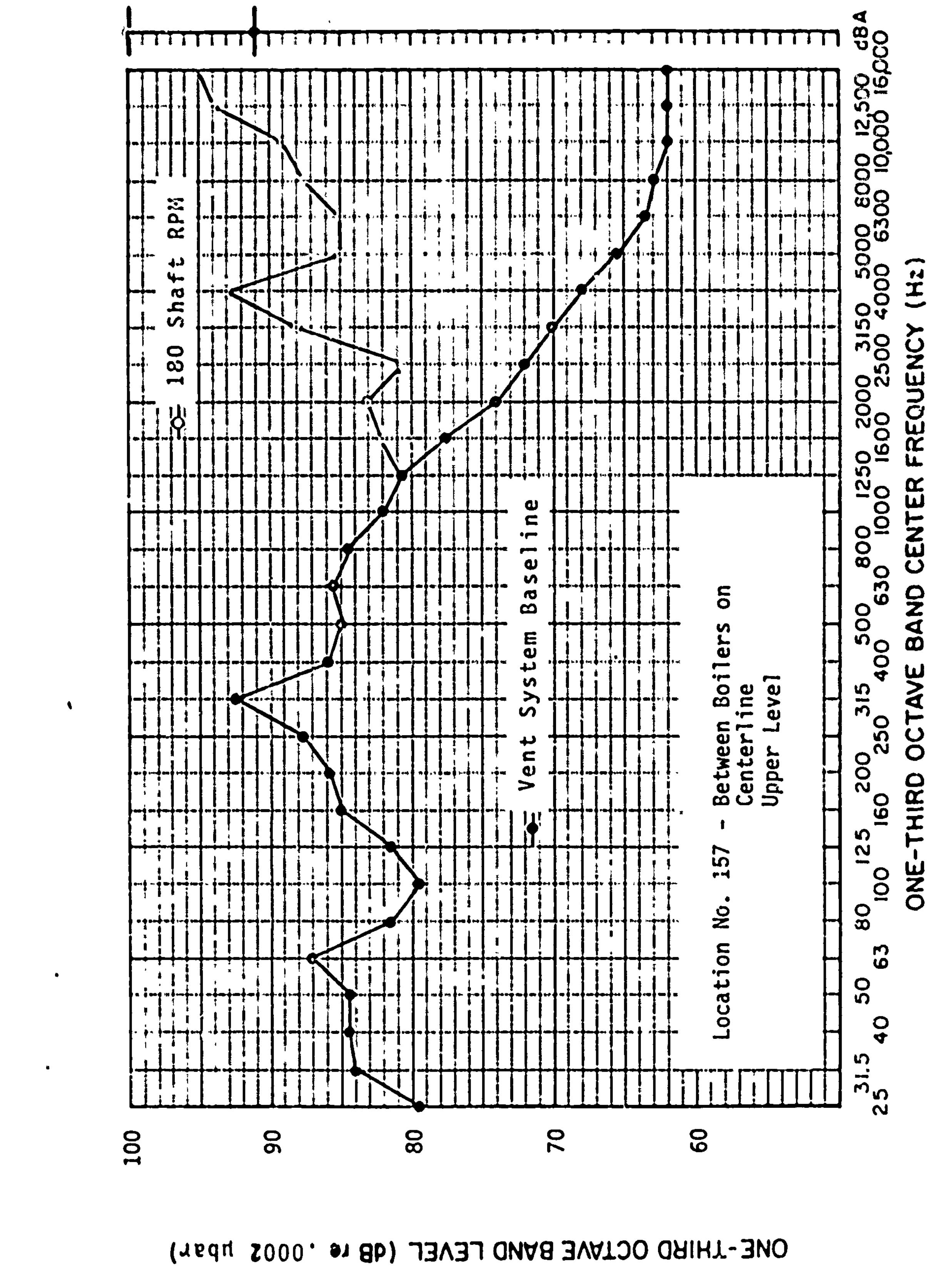


FIGURE 9: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 157 IN FIRE ROOM

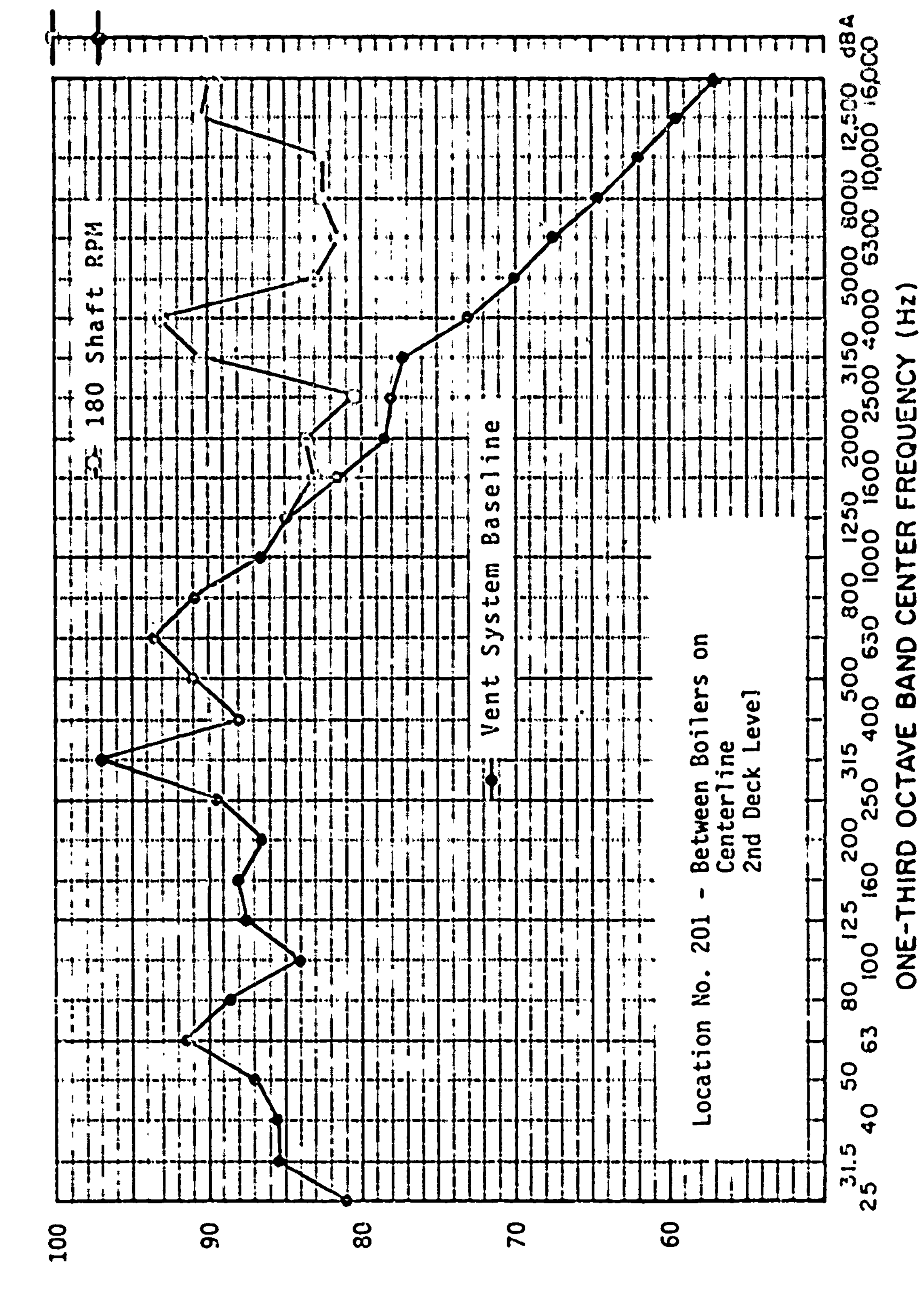


FIGURE 10: USS ELMER MONTGOMERY PRE-RAV NOISE TRIALS MEASUREMENT LOCATION No. 201 IN FIRE ROOM

levels as high as 97 dBA. Cycling of individual vent fans indicated that the dominant sources of vent noise were the two exhaust fans located just above the fire room deckhead in the uptake space. These exhaust fan openings also provide an airborne flanking path for noise from the forced draft blower intakes in the uptake space. Since the vent exhaust fans alone cause excesses above the 90 dBA criterion, it is clear that this noise must be reduced.

The noise produced by the forced draft blowers is characterized by tones occurring at blade passage rates. These tones shift in frequency as a function of blower speed. At normal blower operating speeds, the tones appear at frequencies above 1000 hertz which is the region of the spectrum which most heavily influences the A-weighted levels. Referring again to Figures 6 through 10, the blower tones can be observed in the 2000, 4000 or 5000 hertz bands at each of the five locations. It can also be observed that the tones are a significant, and in some cases, the dominant contributor to the overall noise level. It is, therefore, apparent that reduction of the forced draft blower noise should produce a significant improvement in the overall noise levels in the fire room.

3.0 Auxiliary Machinery Rooms

Underway and dockside measurement were conducted in AMR No. 1 and No. 2. Underway measurements in AMR No. 1 with normal machinery lineups indicate that the noise levels, while uncomfortably high, are not hazardous. The highest continuous noise levels measured were 91 dBA within three feet of a turbo-generator, a location not continuously occupied. Operation of the fin stabilizers produced periodic increases in the noise level which were noticeable but not hazardous, in view of the transient nature of the noise produced.

AMR No. 2 is a partitioned space with the watchstation isolated from the machinery. Normal machinery lineups did not produce hazardous noise levels. When the emergency diesel generator is in operation, hazardous noise levels are generated which are well in excess of 90 dBA. The diesel generator is, however, tightly partitioned from the rest of the AMR, and when the partition door is tightly closed, the hazardous noise is confined to the diesel compartment. Consequently, no additional noise reduction is required from a hearing damage standpoint. Hearing protectors are required, however, when the diesel compartment is entered while the diesel is in operation. The diesel compartment is not continuously occupied while the diesel is operating.

B. Selection and Design of Noise Reduction Treatment

The range of alternatives available for noise reduction treatment for ELMER MONTGOMERY were limited by the "rather strenuous" time constraints. Lead time required for ordering materials which would be compatible with the RAV schedule became a major consideration. A close-coupled treatment for the main reduction gear, that would consist of a composite of damping, isolation and mass loss materials applied directly to the gear casing, was suggested during the planning phase of the program as a potential alternative. Several applications of such treatment had been accomplished previously by NAVSEC and NSRDC personnel (reference 3), but a shipyard installation and a definitive performance evaluation of this type of treatment had not been attempted. An acoustic enclosure represented a potential alternative, the performance of which could be reasonably predicted based on previous application of enclosures to reduce noise from main reduction gears and other types of machinery (reference 7 and 8). Therefore, the selection of a close-coupled treatment for application to the main reduction gear provided the opportunity to definitively evaluate a shipyard-installed close-coupled treatment.

In the design of the close-coupled treatment for the main reduction gear, several alternative materials were available for consideration. Also, an additional constraint was placed on this installation over those previously installed in that a steel cover over the basic treatment was deemed necessary for safety reasons. Therefore, laboratory experiments were conducted to test the relative effectiveness of alternative damping methods, absorption materials and the impact of the steel cover on the overall treatment effectiveness. The results of the tests, which are described in Section II.F, showed that damping tile was superior to chromated felt and spectum plate, and that fiberglass performed better than acoustical closed cell foam material. The tests also indicated that the steel cover could reduce the treatment effectiveness, but this reduction could be minimized by careful isolation attachment of the cover.

The basic configuration of the selected treatment for the main reduction gear, its foundation and main engine foundations, consisted of damping tile to be applied directly to the gear casing and foundation surfaces, overlaid with a fiberglass blanket followed by a layer of limp mass lead vinyl. This composite would be covered by 16-gauge steel attached with resilient studs. A sketch of the cross-section of the selected close-coupled treatment is shown in Figure 11. At locations where the possibility of oil contamination existed, the fiberglass would be enclosed in an impervious bag of

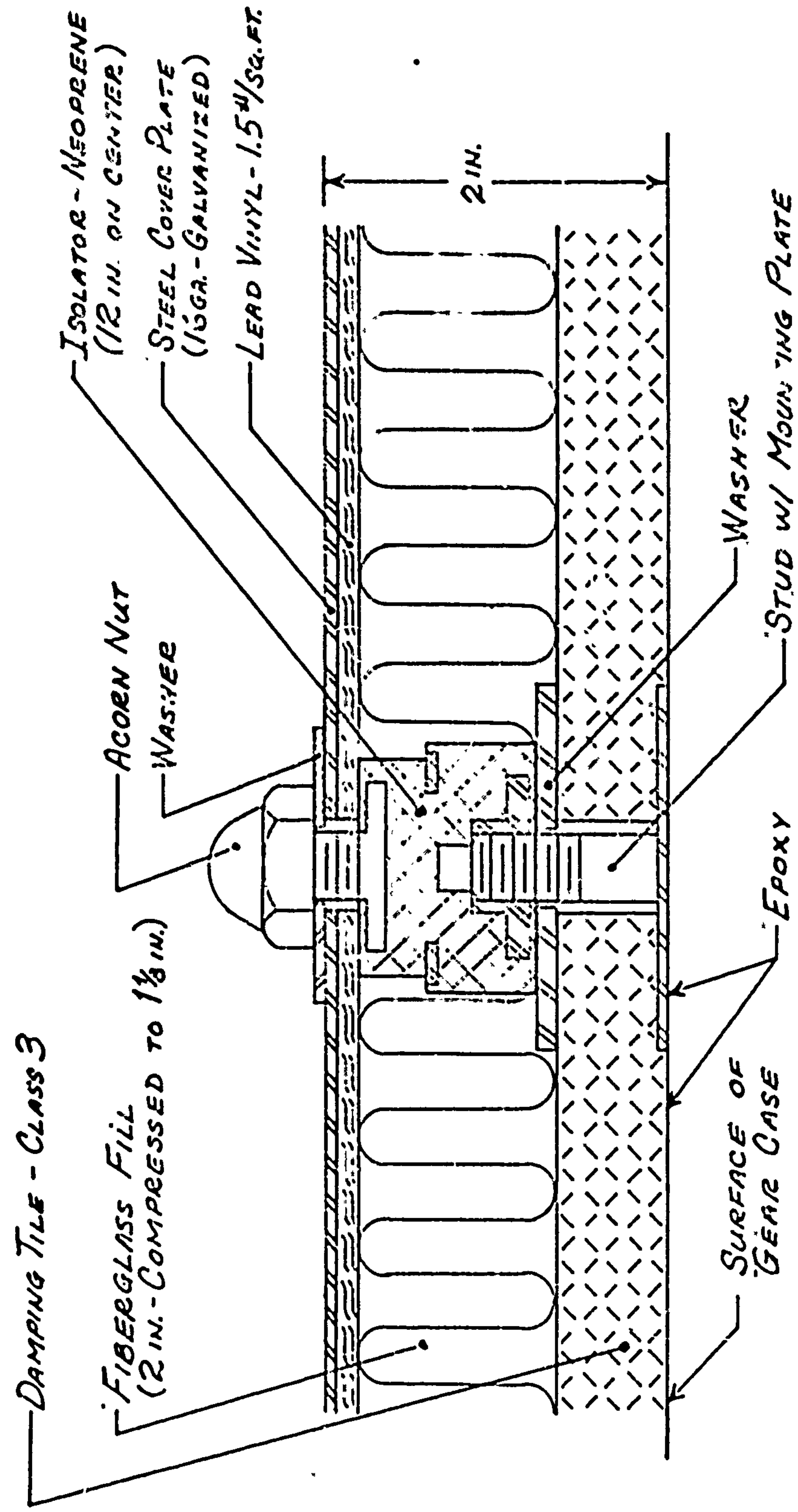
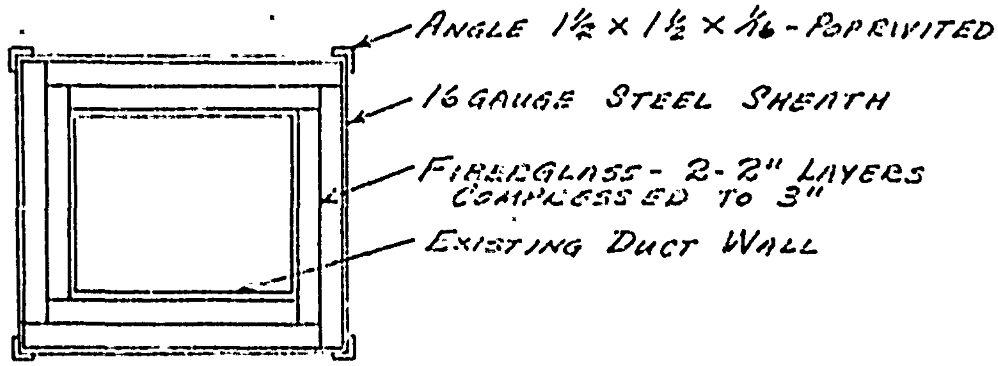


FIGURE 11: CROSS SECTION OF CLOSE-COUPLED TREATMENT SELECTED FOR THE MAIN REDUCTION GEAR AND FOUNDATIONS

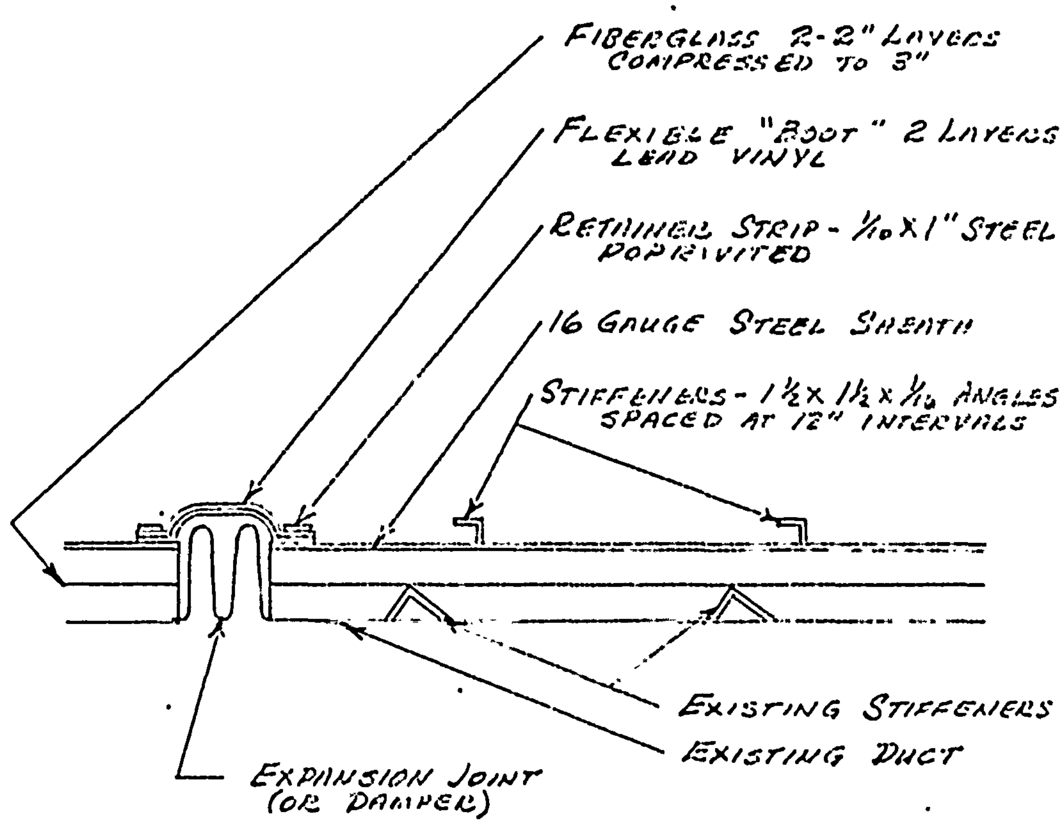
2-mil. thick Mylar film. This basic configuration, accompanied by engineering detail sketches, were used by the shipyard to develop installation design drawings. The basic close-coupled treatment would be augmented where necessary by soft patches and acoustical panels in those areas where installation of the close-coupled treatment was impractical or undesirable from a maintenance or access standpoint.

The forced draft blower ducts required a somewhat different solution in that the noise generating mechanism was different from that of the main reduction gear. The forced draft blower noise in the fire room essentially results from airborne noise inside the duct being transmitted through the duct walls. Therefore, an acoustical lagging for the ducts which would increase the transmission loss of the duct wall was determined to be the appropriate solution. The materials selected for the lagging based on performance and availability were a fiberglass blanket covered with a steel sheath. Soft patches of lead vinyl would be used to cover expansion joints and dampers where the use of a steel sheath would be impractical. Details of this treatment are shown in Figure 12. Again, engineering sketches were provided to the shipyard for guidance in developing installation detail drawings.

The ventilation system noise in the fire room required a third type of noise control solution in that the noise contributed to the fire room was by an airborne path from the exhaust fan openings. A circular, louvered acoustical baffle or inverted top-hat was first considered as the simplest form of treatment; however, a ship check indicated that sufficient clearnace from obstructions was not available. On the smaller, less noisy fan sufficient clearance was available for a simple flat baffle, as shown in Figure 13, and this approach was selected in the interest of economy. On the larger fan there was less clearance and the noise reduction of a simple baffle was considered inadequate.

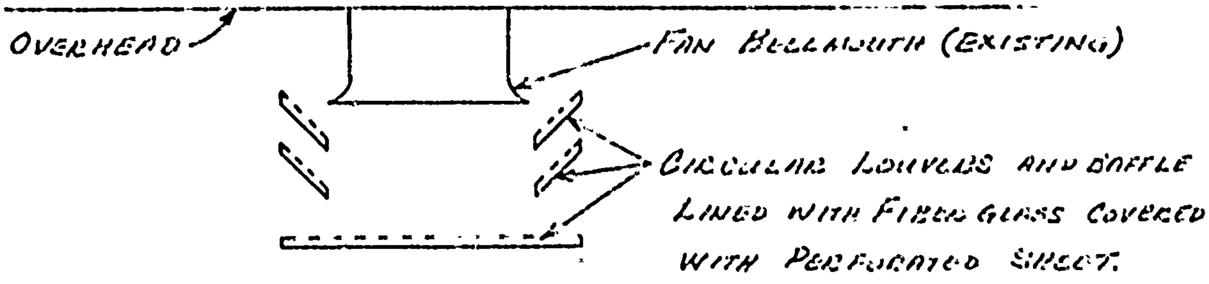


PERPENDICULAR CROSS SECTION

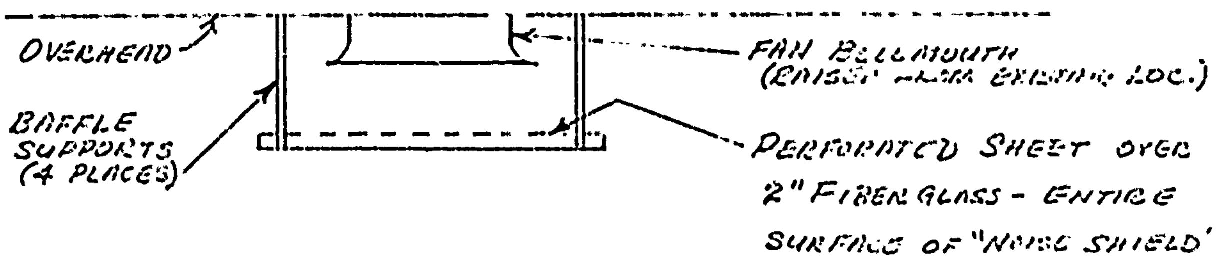


LONGITUDINAL CROSS SECTION

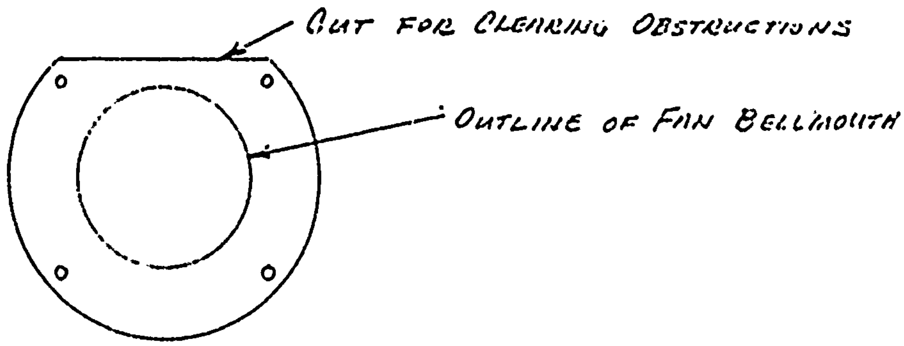
FIGURE 12: CROSS SECTIONS OF FORCED DRAFT BLOWER DUCT TREATMENT



CROSS SECTION OF PROPOSED BAFFLE (ELEVATION)



CROSS SECTION OF INSTALLED BAFFLE (ELEVATION)



PLAN VIEW OF INSTALLED BAFFLE

FIGURE 13: NOISE BAFFLE FOR SMALL VENTILATION EXHAUST FAN FOR THE FIRE ROOM

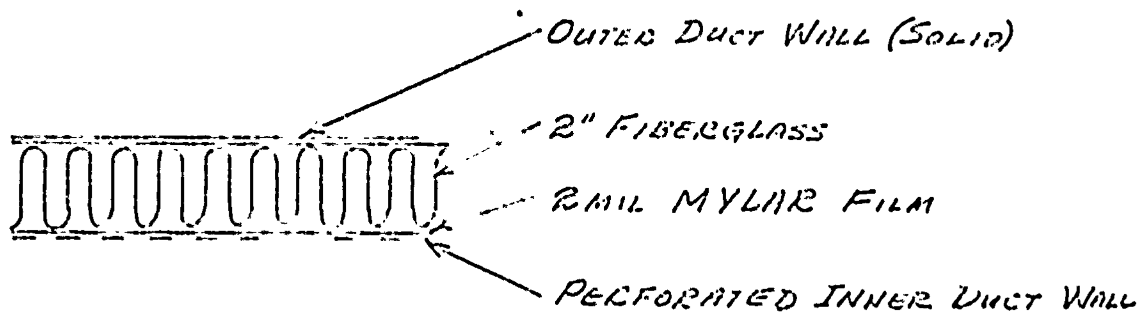
It was, therefore, determined that the exhaust fan should be relocated in the uptake space and reconnected to the fire room opening with acoustically lined ductwork. This ductwork included a straight six foot flanged section which could be replaced with a duct silencer if tests determined the need for additional noise reduction. Details of the large vent fan treatments are shown in Figure 14.

Since the noise data taken during the tests of the Prairie/Masker system were determined to be not representative of a properly functioning system, valid noise data were not available to develop noise control treatment. Therefore, design of noise reduction treatment for this system was deferred pending further tests on a properly functioning system. It was determined, however, that control of the noise from compressor venting during warmup would be a necessary part of the noise reduction treatment for ships in which the vent terminated in the fire room.

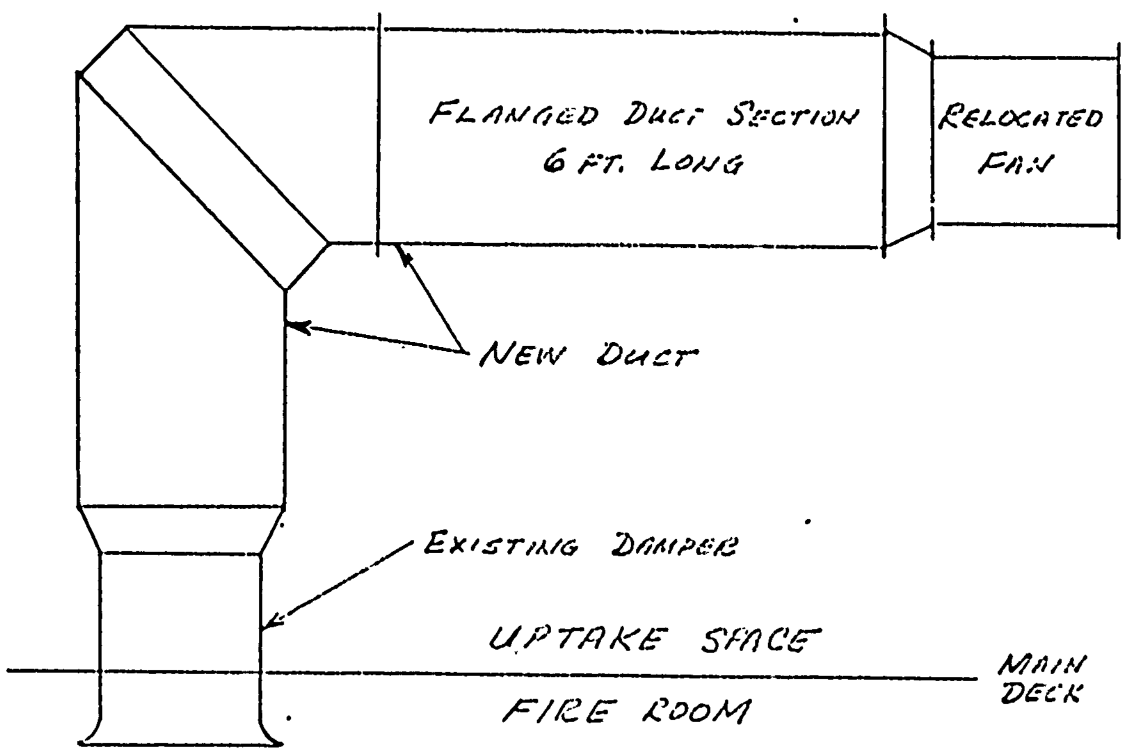
C. RAV Work Description

1.0 Engine Room

In the engine room noise control treatment was limited to the main reduction gear, its foundation and the turbine foundations. The free surfaces of the main reduction gear casing and the foundations were covered with the close-coupled composite treatment as shown in Figure 11. Essentially complete enclosure of the gear casing was achieved, with soft patches over flanges and fittings not covered by the basic treatment. The soft patches, which consisted of two layers of lead loaded vinyl filled with fiberglass, were installed to be removable for maintenance access. Inspection ports on the gear were provided with covers constructed with 16-gauge steel, lined with fiberglass which was held in place by perforated aluminum. The covers were held in place with latches for maintenance removal. In areas where the fiberglass would be exposed to oil contamination, the fiberglass was enclosed in Mylar film.



CROSS SECTION OF NEW DUCT WALL



ELEVATION LOOKING AFT

FIGURE 14: TREATMENT OF LARGE VENTILATION EXHAUST FAN FOR THE FIRE ROOM

The lower foundation area was completely enclosed by the treatment. The close-coupled treatment was installed on all outer surfaces. Gaps between the turbine foundation pedestals and the main condenser were closed with removable acoustical panels. Inspection and access ports were covered with removable acoustic covers. The extent and location of the noise reduction treatment are shown in Figure 15.

External lube oil piping for the main reduction was to have been lagged; however, this work was not completed during the RAV. A very few closures in the gear case treatment (i.e., soft patches) were either left off or not completed at the end of the RAV. While these deficiencies are minor from a work completion standpoint and are probably the result of a tradesman's unfamiliarity with material, they can be significant from an acoustical standpoint, particularly in the case of the lube oil piping upon which high vibration levels were measured.

2.0 Fire Room

The noise reduction work in the fire room included the acoustical lagging of the forced draft and lighting-off blower ducts and treatment of the ventilation exhaust fans. The foreced draft blower duct lagging consisted of a 4-in. layer of fiberglass blanket covered with, and compressed to a nominal 3-in. thickness by a 16-gauge steel sheath. The entire area, excluding expansion joints and damper sections, of the four forced draft blower ducts and associated lighting-off blower ducts was lagged with this treatment. Expansion joints were enclosed by a flexible boot of lead-loaded vinyl. Duct dampers were also covered with the flexible lead-loaded vinyl boot so that the entire duct areas from overhead to boiler were covered, except for a small gap at the overhead. Many of these boots were not properly sealed at the end of the RAV, again

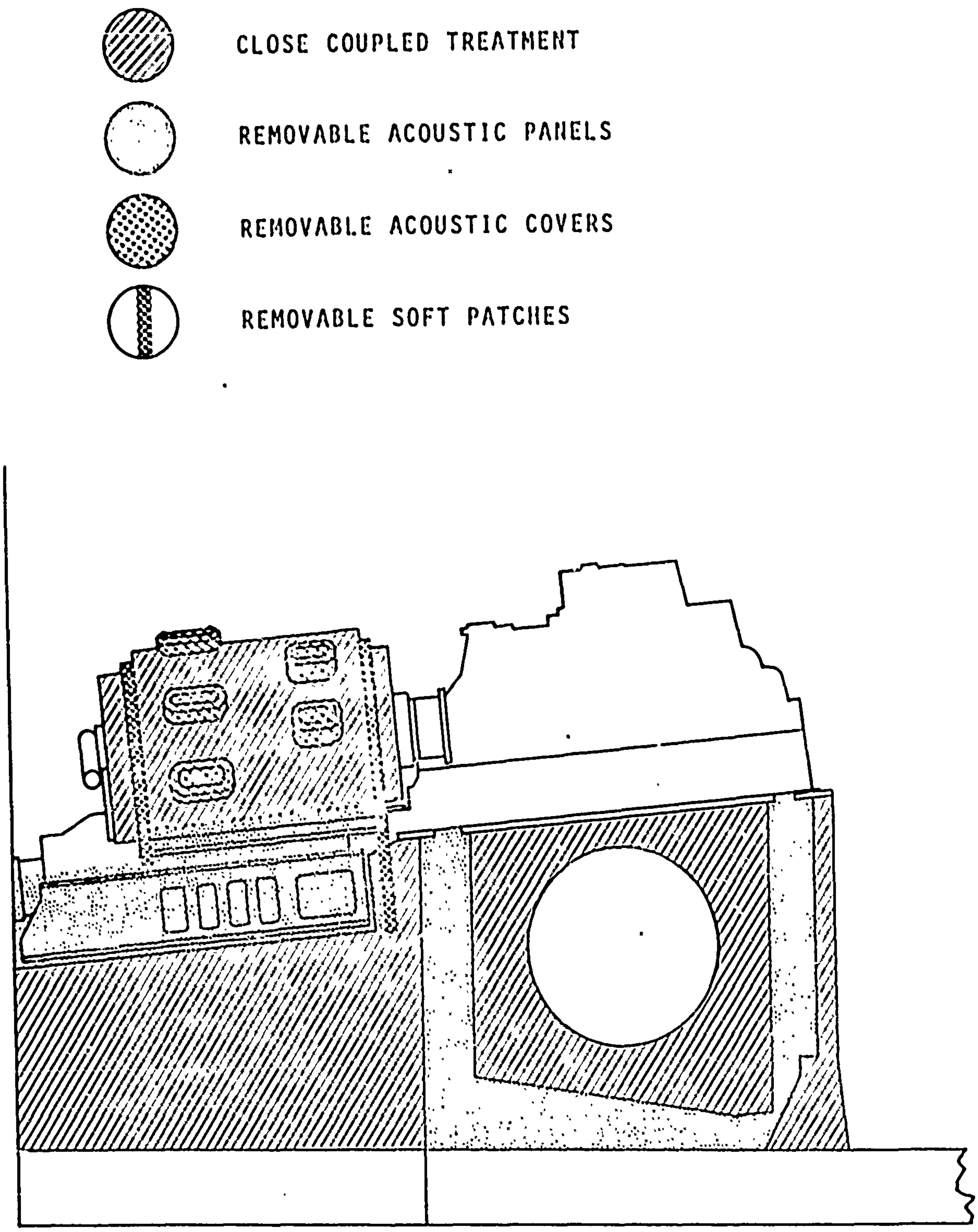


FIGURE 15: NOISE REDUCTION TREATMENT ON MAIN REDUCTION GEAR AND GEAR AND TURBINE FOUNDATIONS

probably due to tradesman's lack of familiarity with the material, which resulted in noticeable noise leaks around the boots.

On the smaller of the two vent exhaust fans, a flat circular baffle, covered on the upper side by fiberglass under perforated aluminum, was hung below the bellmouth. This baffle was a significant compromise of the design originally proposed. The original design was intended to block line-of-sight paths from the bellmouth. The compromise was necessary due to limited clearance in the vicinity of the fan bellmouth, and other alternative solutions would have been more costly. The design was further compromised by rather large cutouts required for piping clearances.

The clearance around the bellmouth of the larger fan ruled out entirely the possibility of an acoustical baffle. It was necessary, therefore, to relocate this fan within the uptake space. The fan was remounted horizontally approximately six feet athwartships to port from its original position. The fan was then reconnected to the original opening using an acoustically lined duct and a 90-degree elbow. A straight three-foot long flanged section was included in the duct which could be replaced at a later date with a duct silencer if additional noise reduction proved to be needed. This treatment of the large fan was by far the more superior of the two fan treatments.

D. Post RAV Noise Trial Description

Noise reduction evaluation trials were conducted in USS ELMER MONTGOMERY (FF 1082) subsequent to its departure from the shipyard during the period 28 November through 7 December 1975. The trials were designed to measure the performance of the prototype noise reduction treatments installed during the restricted availability (RAV). This objective would be accomplished by comparing noise measurements with the treatments installed with comparable measurements conducted prior to the RAV.

The results of noise measurements taken in the engine room and fire room with the noise reduction treatments installed are described below and compared to noise measurements taken prior to the installation of the treatments.

1.0 Engine Room

Measurement locations used in the pre-RAV noise trial were selected which would be representative of the distribution of noise levels within the space and would also reflect the improvement in noise levels resulting from the noise reduction treatment. Table 3 shows noise levels at nine measurement locations as single number dBA values as a function of ship speed expressed in shaft RPM. Due to the need to share operating time with other test activities not associated with noise reduction, the measurements taken during the post RAV trial below 160 RPM were not taken at the same speeds as the pre-RAV measurements; however, measurements were taken at more speed increments and the levels shown in Table 3 are considered to be reasonably indicative of the noise levels at the speeds shown. For comparison purposes, the baseline levels representative of the noise produced by the non-propulsion auxiliaries are also shown in the table. From Table 3 it can be seen that noise levels at the two manned locations were below the 90 dBA BUMED 105HA criteria at all speeds through 200 RPM, or approximately 26 knots. One of the manned locations remained below 90 dBA throughout the speed range.

After the treatment was installed the noise levels were within 2 dB of the non-propulsion baseline levels up to a speed of 140 shaft RPM or approximately 18 knots except at locations No. 3 and No. 14, both of which were located within three feet of the main reduction gear. At 140 RPM only four locations exceeded the 90 dBA eight hour criteria and the largest excess was 2 dB. Of the four locations exceeding 90 dBA at 18 knots, one is no higher than the non-propulsion machinery baseline level at that location.

In Figures 16 and 17 the A-weighted levels measured before and after the treatment was installed are plotted as a function of speed for the two manned locations. The difference in levels represents the noise reduction achieved at those two locations with the noise reduction treatment. Figure 16 shows that the influence of propulsion noise has been significantly reduced at location No. 1. At location No. 2, Figure 17, the noise level is essentially independent of propulsion noise at speeds below 20 knots.

One-third octave band levels, measured at 160 shaft RPM or approximately 21 knots both before and after the treatment was installed, are shown in Figures 18 through 22. By inspection of these figures at locations clearly dominated by the gear tones, such as measurement location No. 3, a reasonable measure of the treatment performance can be judged by the reductions achieved at these tone frequencies.

TABLE 3

USS ELMER MONTGOMERY POST-RAV NOISE TRIALS
ENGINE ROOM NOISE LEVELS IN dBA
(WITH TREATMENT INSTALLED)

MEASUREMENT LOCATION	MIKE No.	SHIP SPEED IN SHAFT RPM								NON PROP BASE LINE
		80	100	120	140	160	180	200	220	
*ML - Workbench by A/C Plant #2	1	83	84	85	86	88	87	87	89	84
*ML - Log Desk by Evaps	2	88	88	89	89	89	89	89	94	88
LL - Starboard - Outboard MRG	3	90	90	91	92	94	92	94	93	89
ML - Port - Outboard MRG	5	85	86	88	88	92	90	91	94	85
LL - Port - Outboard MRG	7A	88	88	88	88	95	93	94	93	85
LL - Fwd - Between Fire P. & Circ.P	12	91	90	91	92	95	95	95	97	92
LL - Fwd - Between Cond & Circ P.	13	91	90	90	91	92	93	93	95	89
UL - Center of MRG	14	86	88	89	90	92	92	92	96	84
ML - Fwd - By Main Air Ejector	17	90	90	91	91	91	93	93	95	89

LL - Lower Level ML - Middle Level UL - Upper Level
* Manned Locations

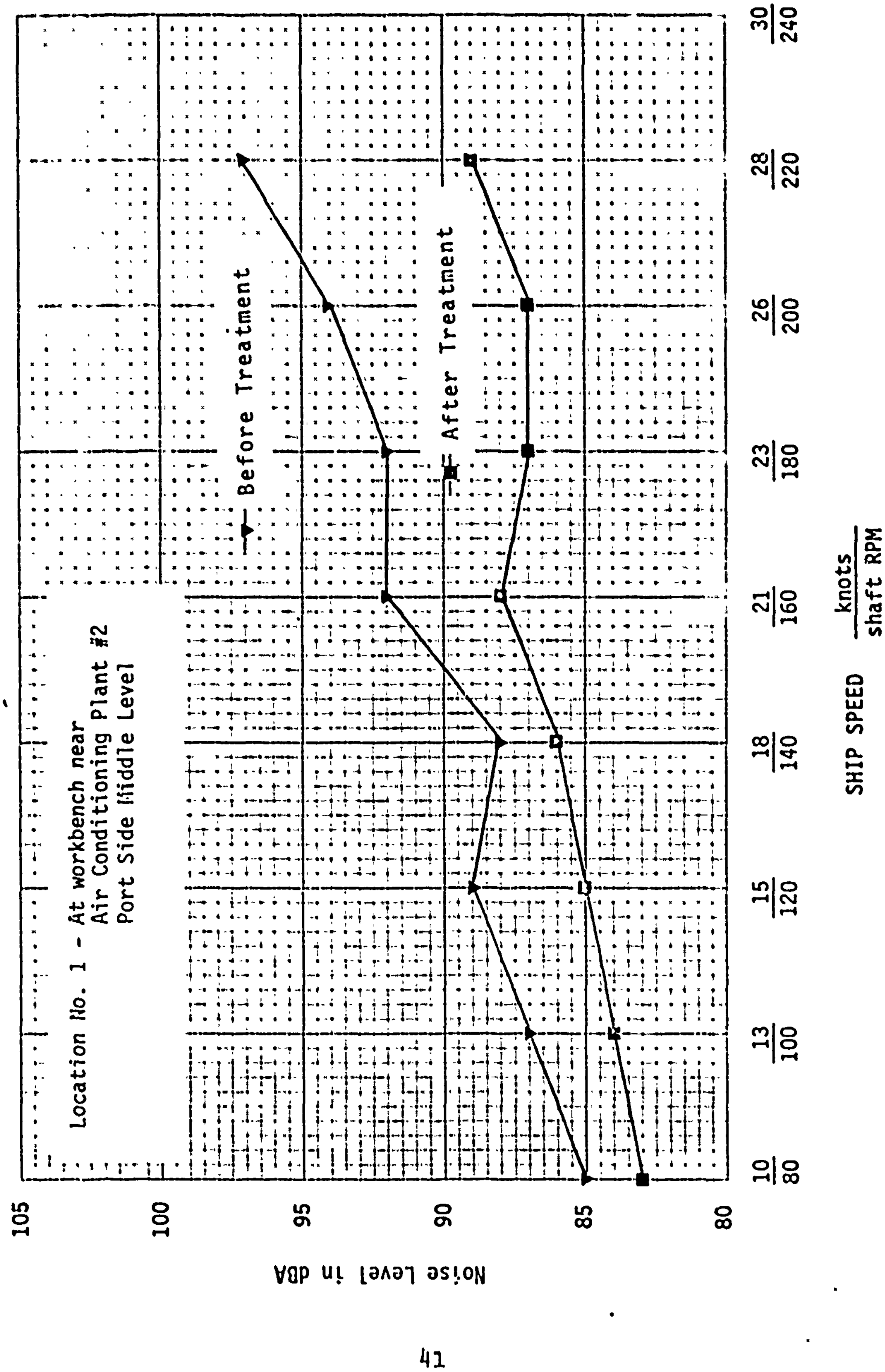


FIGURE 16: COMPARISON OF NOISE LEVELS BEFORE AND AFTER TREATMENT AT LOCATION NO. 1 IN THE ENGINE ROOM

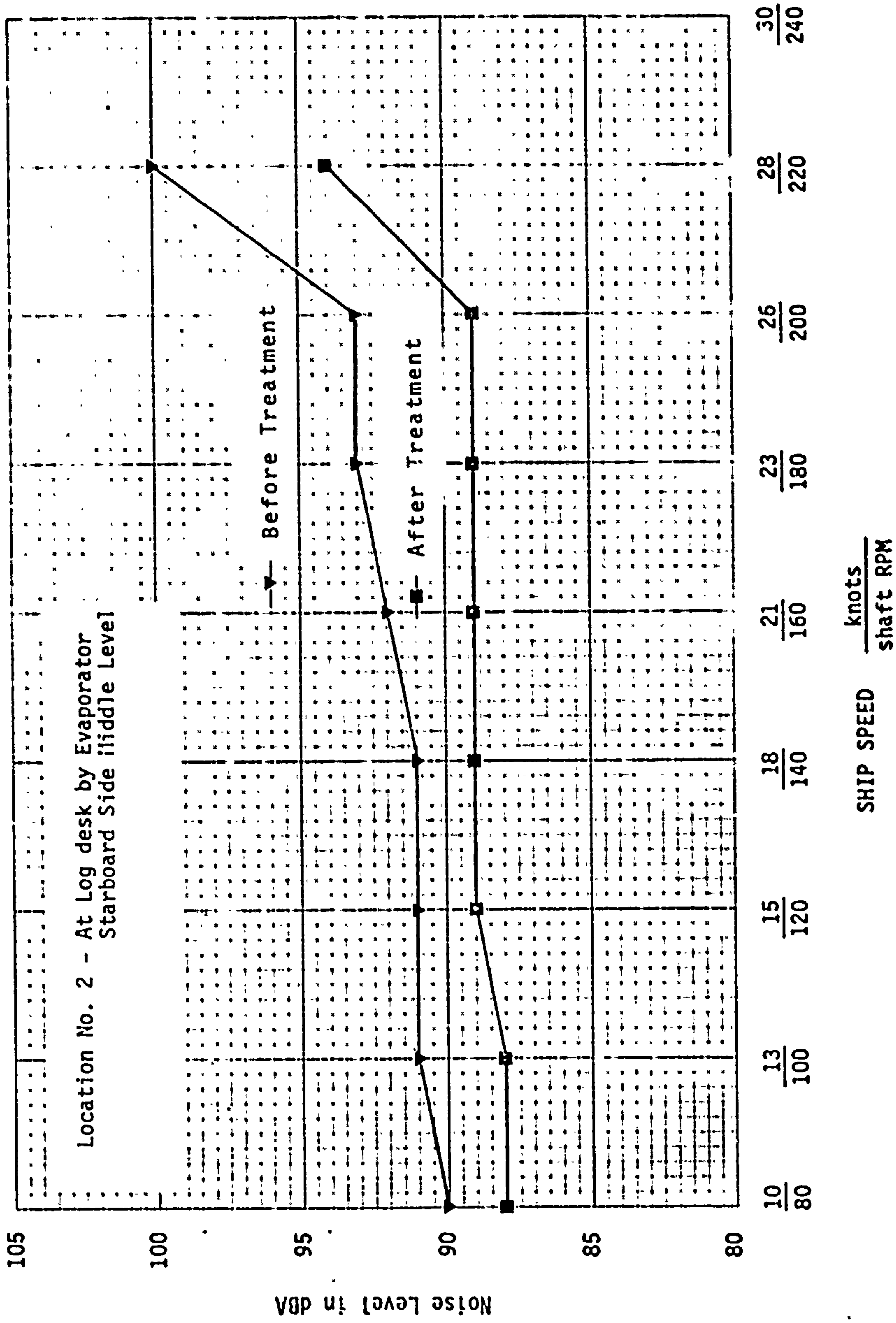


FIGURE 17: COMPARISON OF NOISE LEVELS BEFORE AND AFTER TREATMENT AT LOCATION NO. 2 IN THE ENGINE ROOM

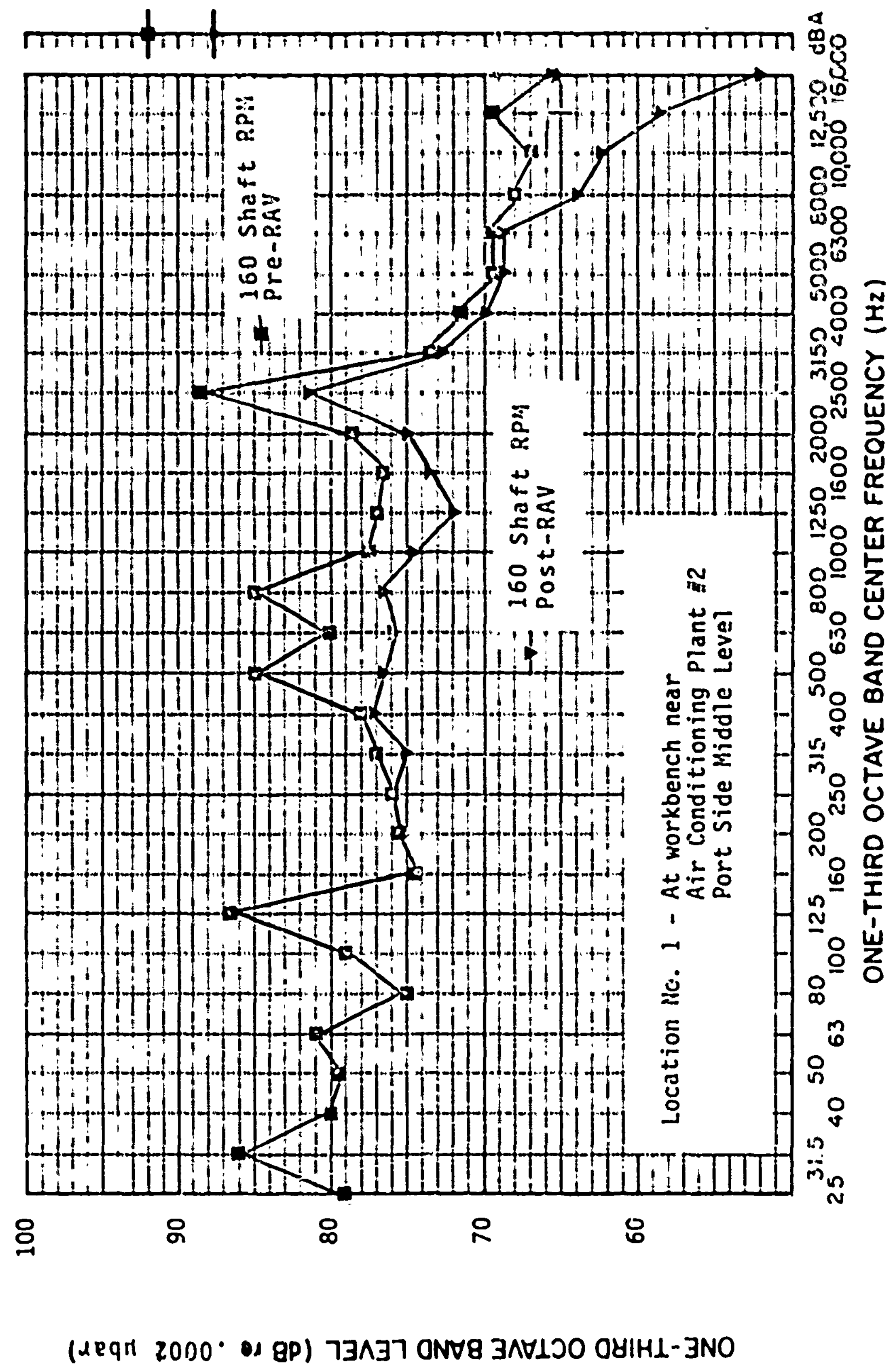


FIGURE 18: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS
MEASUREMENT LOCATION NO. 2 IN ENGINE ROOM

Figure 20, showing the levels at this location indicates that reductions at tone frequencies are on the order of eight to ten decibels.

The gear tone which appears in the 2500 hertz band at 160 shaft RPM has been identified as being generated by undulations in the first reduction gear. These undulations are the result of manufacturing procedures. This tone has been noted in the underwater spectra of other ships in the FF 1052 class equipped with the same type reduction gear. This tone appears to peak in amplitude at 160 shaft RPM, where its frequency is near 2500 hertz and its amplitude is greater than that of the second reduction mesh tone. It is usually expected in double reduction gears of this type that the second reduction gear mesh will produce the strongest tone in the airborne noise spectrum. Observing the A-weighted levels for measurement location No. 3 in Table 3, it can be seen that there is also a peak in the dBA level at 160 shaft RPM which is attributable to the peaking of the first reduction undulation tone.

2.0 Fire Room

In the fire room, measurement locations were also replicated in the post-RAV tests that were used in tests conducted before the treatment was installed. A summary of the post-RAV noise levels expressed in dBA values as a function of ship speed expressed in shaft RPM are tabulated in Table 4. Since the noise levels measured at 160 RPM were all 90 dBA or below, it was considered unnecessary to collect data for all of the speed increments below 160 RPM. Therefore, data were taken at a speed of 120 RPM as a spot check

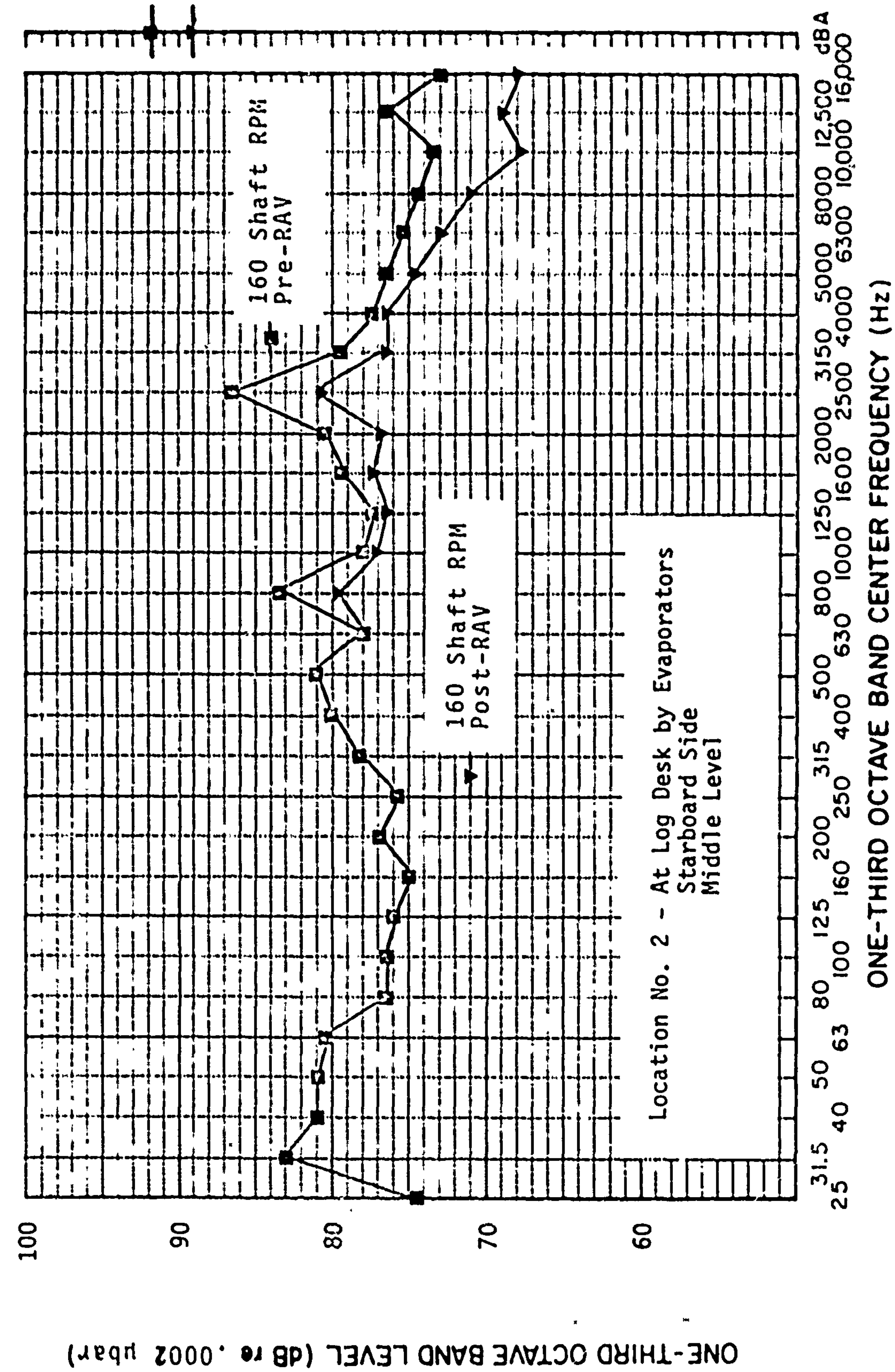


FIGURE 19: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 2 IN ENGINE ROOM

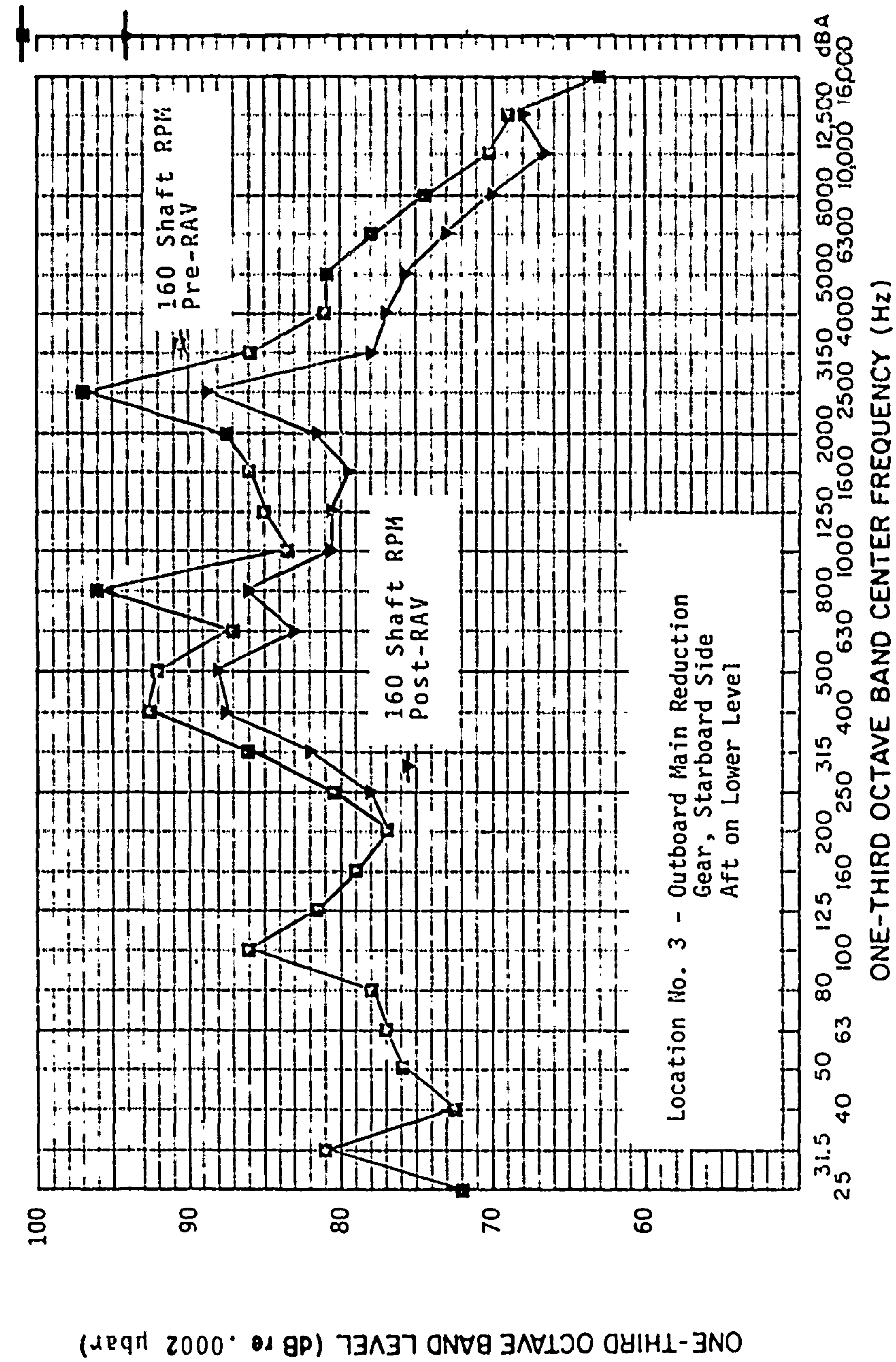


FIGURE 20: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS
MEASUREMENT LOCATION NO. 3 IN ENGINE ROOM

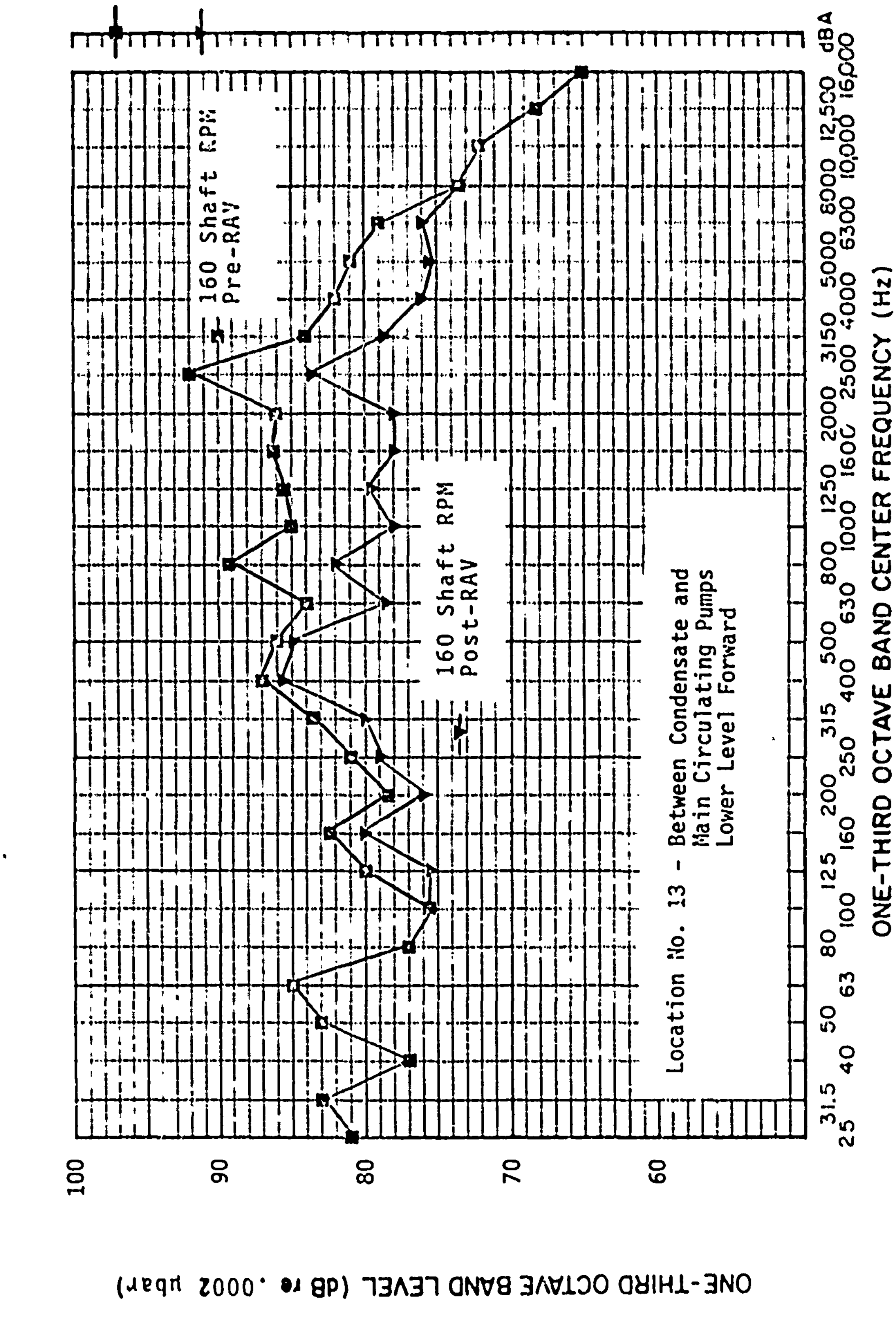


FIGURE 21: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 13 IN ENGINE ROOM

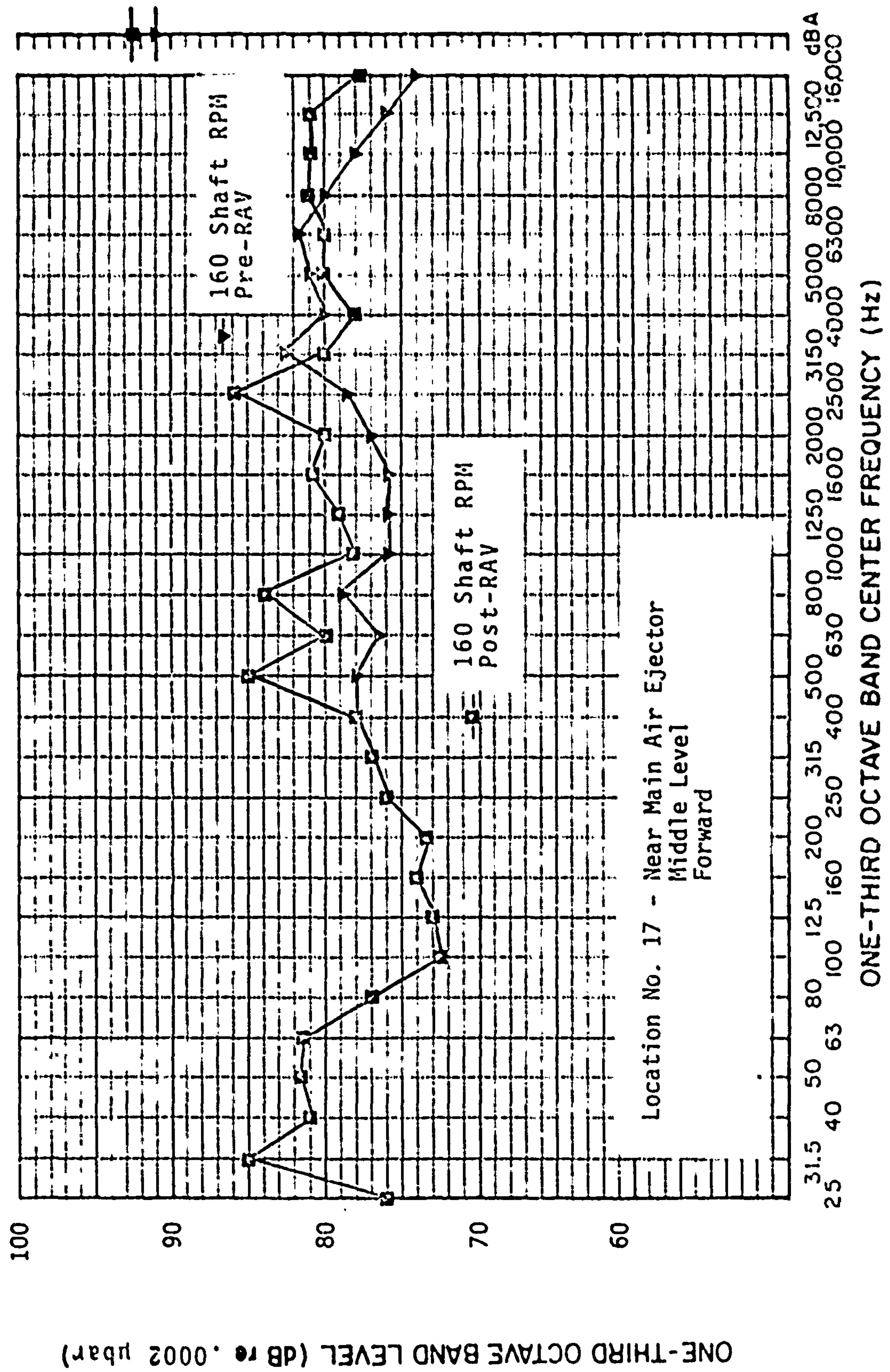


FIGURE 22: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 17 IN ENGINE ROOM

TABLE 4

USS ELMER MONTGOMERY POST-RAV NOISE TRIALS
FIRE ROOM NOISE LEVELS IN dBA
(WITH TREATMENT INSTALLED)

MEASUREMENT LOCATION	MIKE No.	SHIP SPEED IN SHAFT RPM							
		80	100	120	140	160	180	200	220
*LL - At Burner Clng Bench	58			89		89	89	89	93
*LL - Between Boilers Starboard Side	81A			88		83	91	93	97
LL - Near P/M Comp #1B	82			83		85	86	88	89
UL - Near Main Feed Pump #1C	88			85		86	88	88	91
LL - Near Fire Pump #2	104			80		84	86	83	95
*UL - At Workbench Port Side	155			85			86	87	92
UL - Between ladders Port Fwd	156			84		86	85	85	91
UL - Between Boilers on Centerline	157			89		89	90	91	95
UL - Near Main Feed Pumps #1A & 1B	158			90		90	91	91	92
2D - Between Boilers on Centerline	201			90		90	91	92	94
2D - At ladder to FD Blr Room	202			85		88	88	88	90

LL - Lower Level UL - Upper Level 2D - 2nd Deck Level
*Manned Locations

of the expected data trend below 160 RPM. All measurements at 120 RPM were the same or lower than the levels at 160 RPM, as would be expected.

From Table 4, it can be seen that noise levels measured with the treatments installed, were at or below the 90 dBA criteria at 160 shaft RPM or approximately 21 knots. This compares to levels as high as 99 dBA which were measured before the RAV. At 200 shaft RPM, or approximately 26 knots, more than half the measurement locations remained below 90 dBA, with the highest level reaching only 93 dBA. This compares with levels as high as 103 dBA before the RAV, with all measurement locations exceeding the 90 dBA criteria.

Table 4 shows that noise levels at manned locations are below the 90 dBA criterion at speeds up to 180 RPM, or approximately 23 knots. At the two workbench locations, noise levels are below the criteria at all speeds up through 200 RPM or approximately 26 knots.

In Figures 23 and 24 the A-weighted noise levels measured before and after the treatments were installed are plotted as a function of speed for two of the manned locations. The noise reduction achieved at those locations is depicted by the difference in the measured levels. It can be seen from the two figures that the noise reduction achieved at location 155, Figure 24, is much greater due to its closer proximity to the treated forced draft blower ducts and vent fans.

Comparison of one-third octave band levels measured at 180 shaft RPM, or approximately 23 knots, before and after the treatments were installed are shown for five representative locations in Figures 25 through 29. These figures

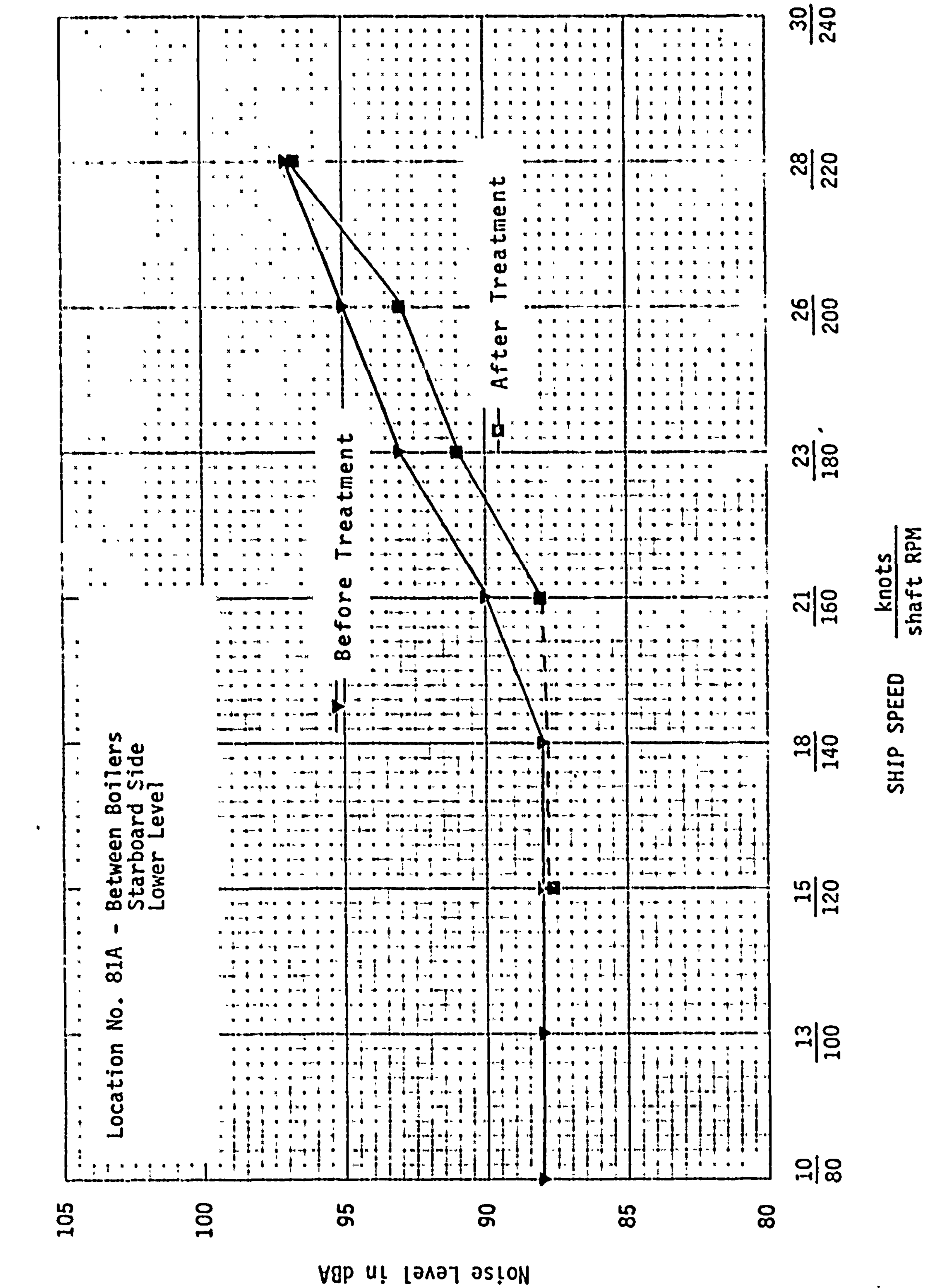


FIGURE 23: COMPARISON OF NOISE LEVELS BEFORE AND AFTER TREATMENT AT MEASUREMENT LOCATION 81A IN THE FIRE ROOM

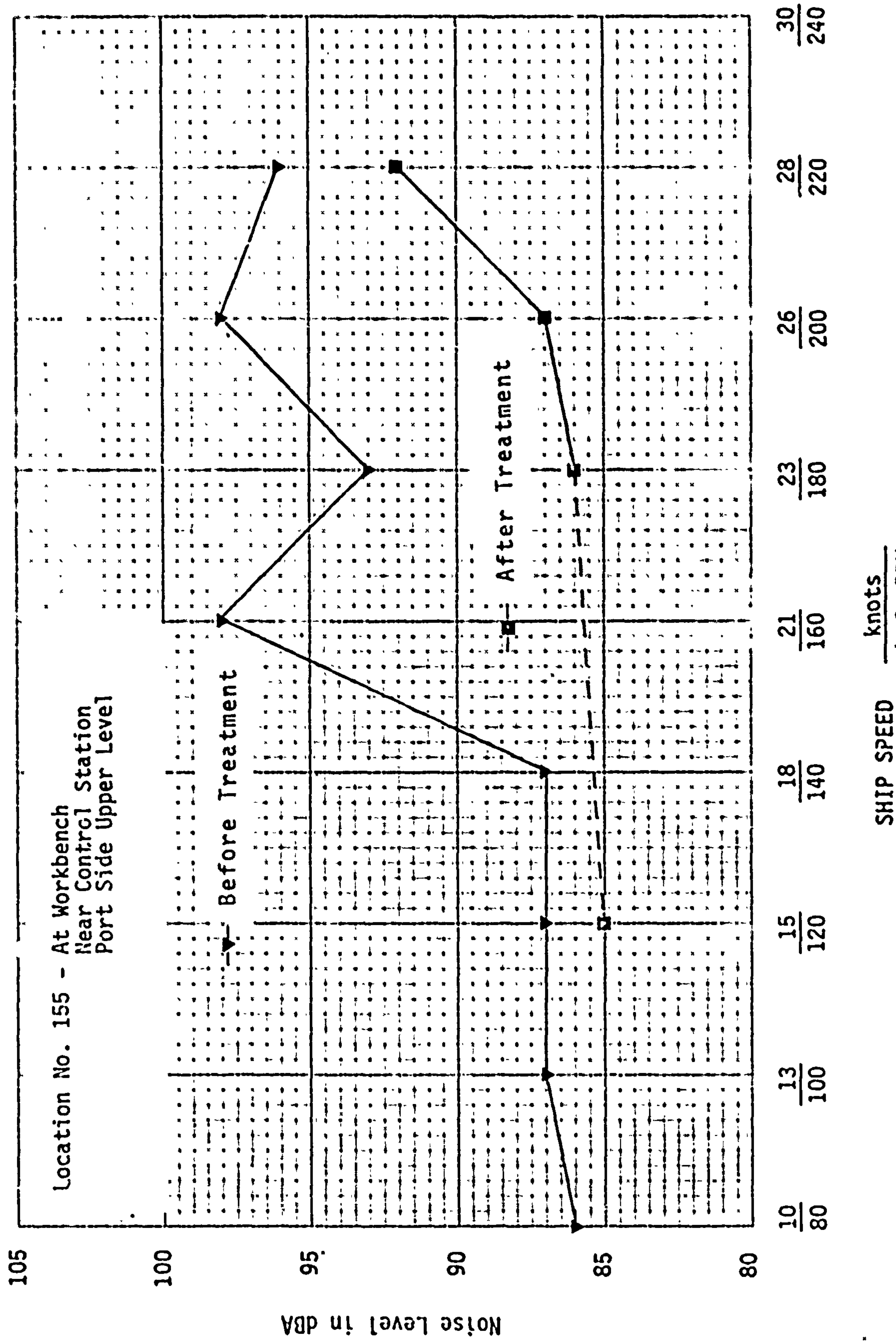


FIGURE 24: COMPARISON OF NOISE LEVELS BEFORE AND AFTER TREATMENT AT MEASUREMENT LOCATION NO. 155 IN THE FIRE ROOM

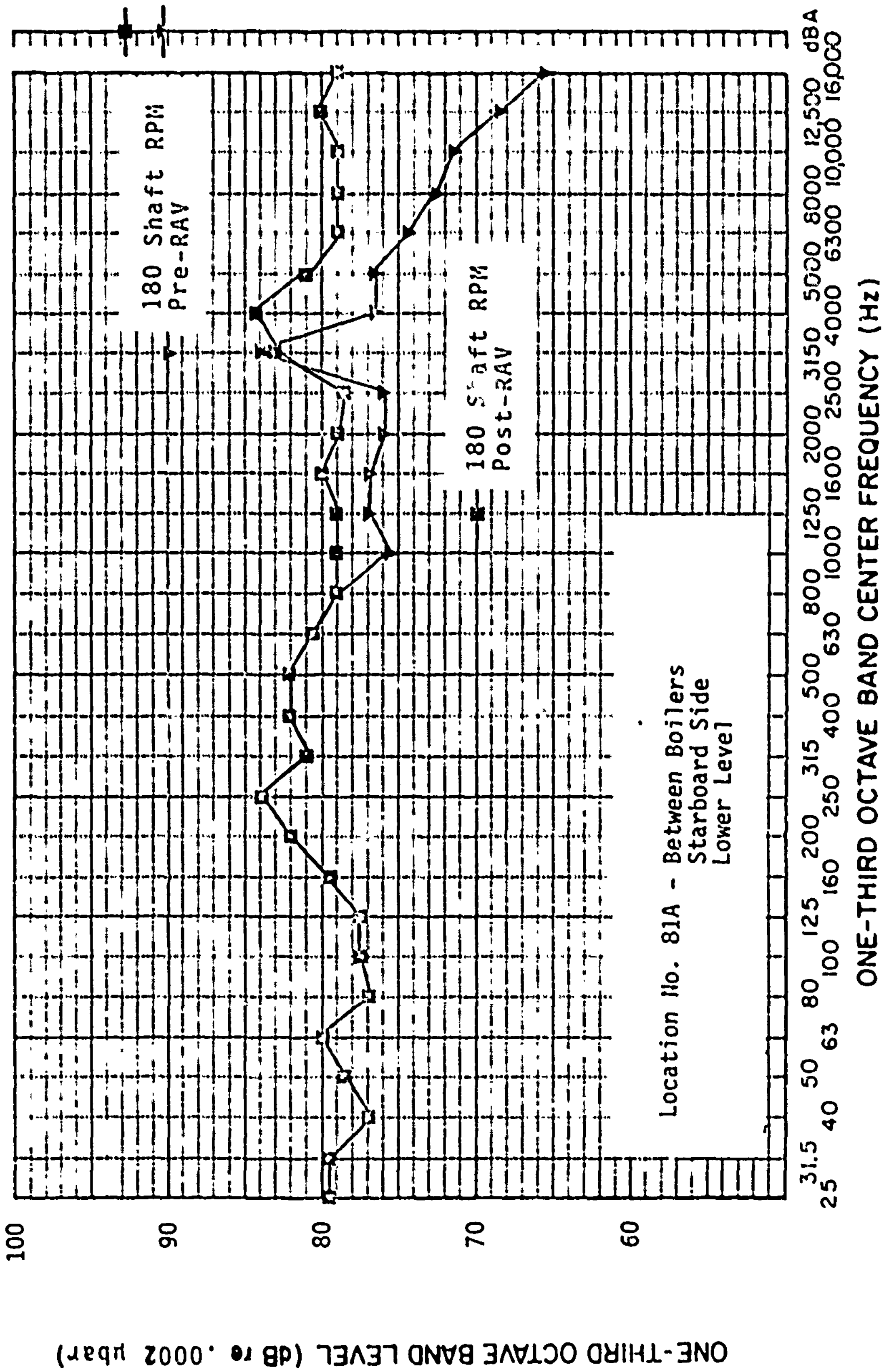


FIGURE 25: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS
MEASUREMENT LOCATION NO. 81A IN FIRE ROOM

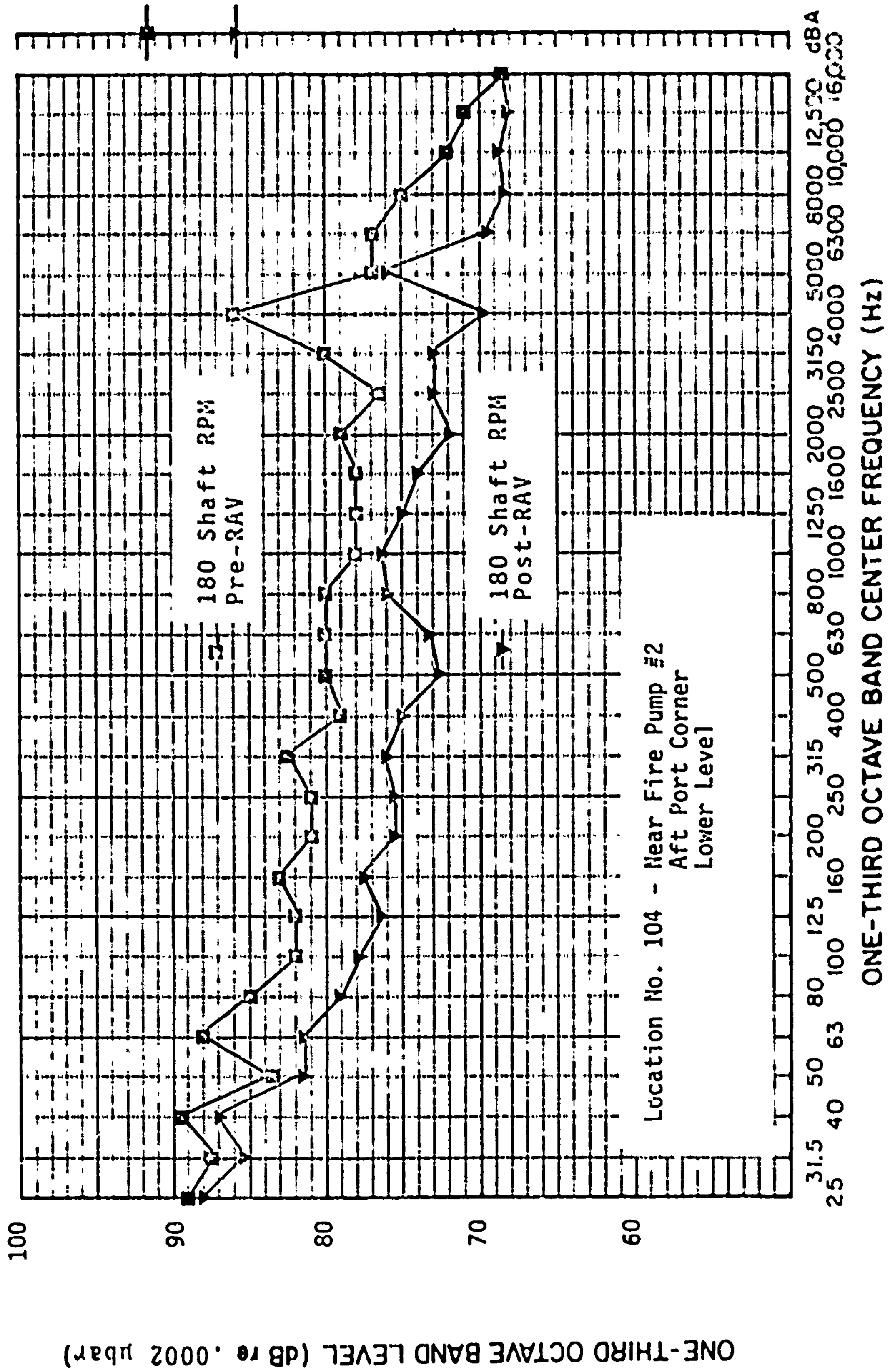


FIGURE 26: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS
MEASUREMENT LOCATION NO. 104 IN FIRE ROOM

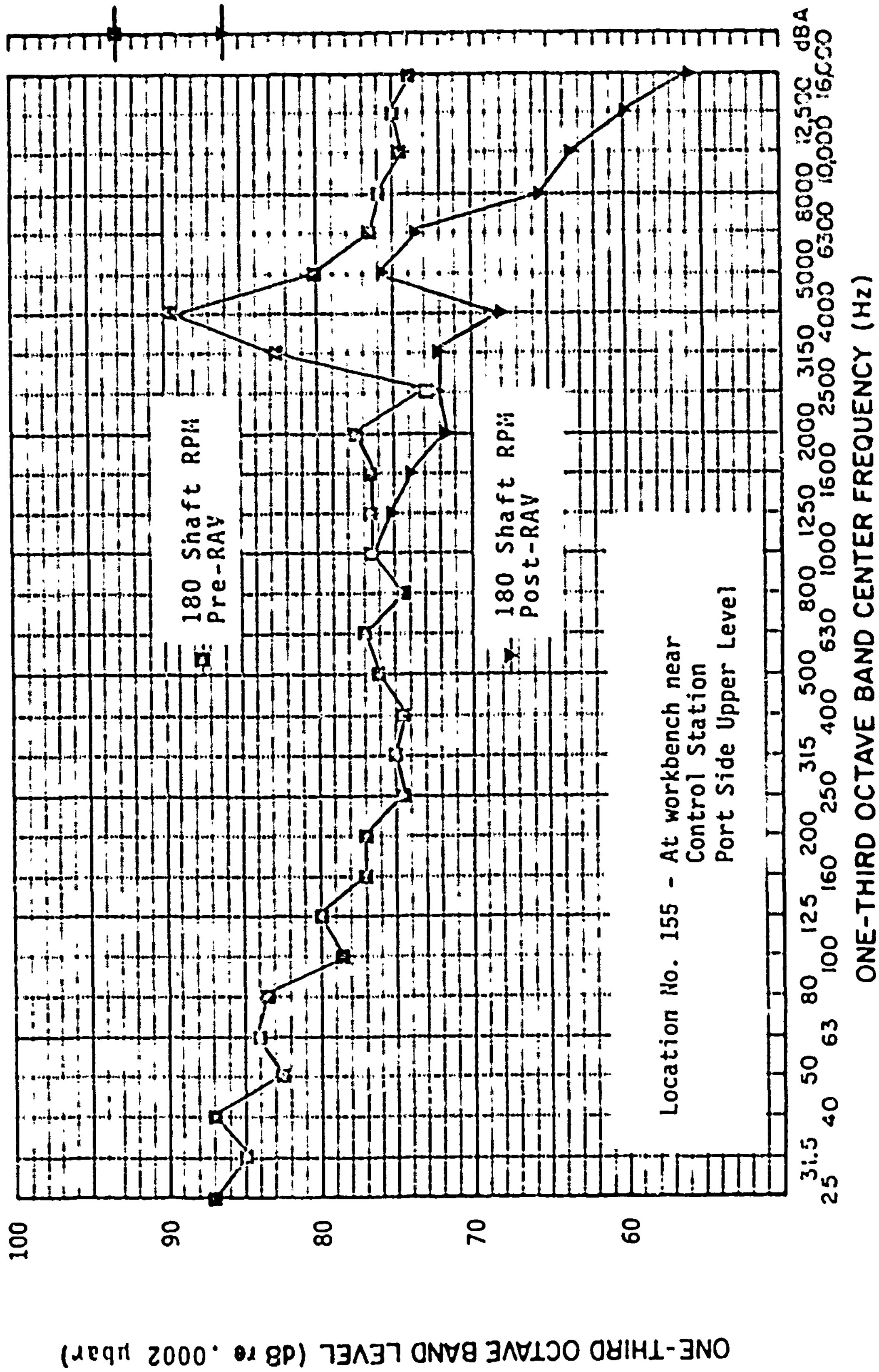


FIGURE 27: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 155 IN FIRE ROOM

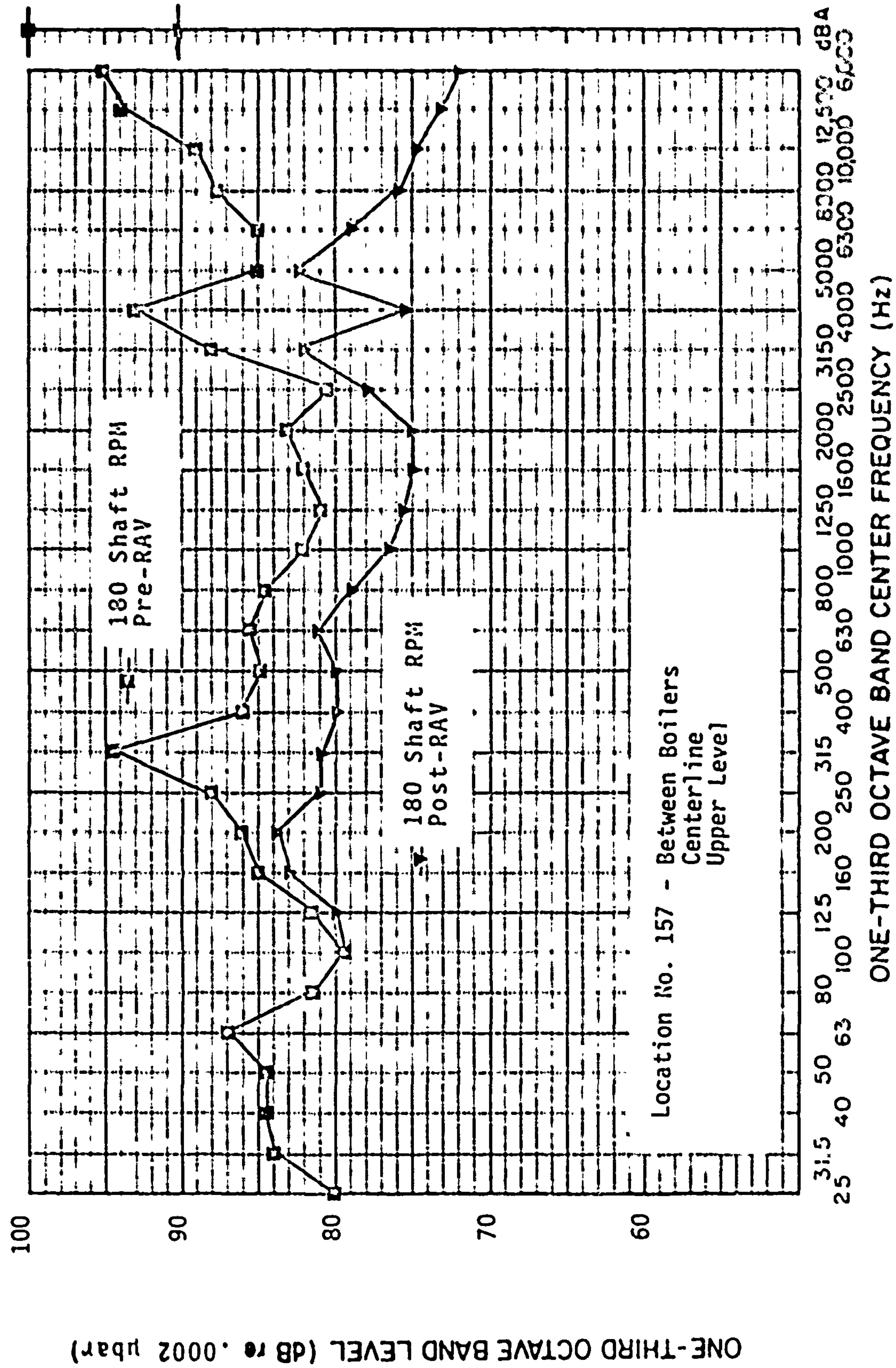


FIGURE 28: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS MEASUREMENT LOCATION NO. 157 IN FIRE ROOM

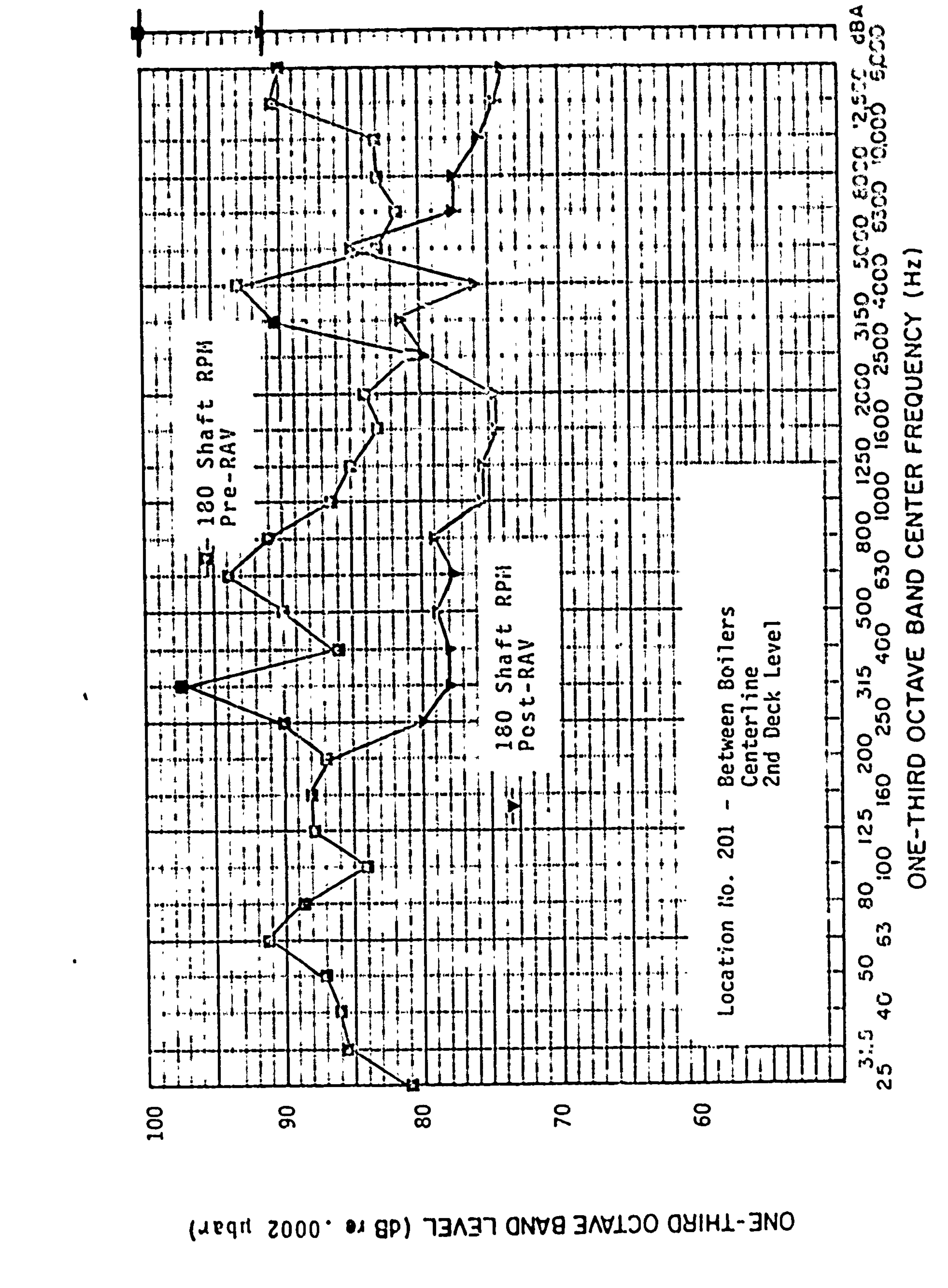


FIGURE 29: COMPARISON OF PRE-AND POST-RAV NOISE TRIALS
MEASUREMENT LOCATION NO. 201 IN FIRE ROOM

show that the forced draft blower tones, while substantially reduced, are still significant contributors to the A-weighted noise levels. This suggests that completion of the finish work on the flexible boots on the forced draft blower ducts should improve the overall performance of this treatment and further reduce the existing levels.

During the RAV, ship's force performed maintenance on the Prairie/Masker emission systems. Therefore, tests were conducted underway to determine if a properly functioning system produced excessive noise levels. Since the inboard vent was not altered during the RAV, the severe noise problem during compressor warmup still remains. During the underway tests, the emission systems would not absorb the output of both compressors with the inboard vent closed, thus the compressors would overspeed. It was, therefore, necessary to test the compressors by running them one at a time. During the operation of each compressor, noise levels increased to 91 dBA in the immediate vicinity of the compressor. One compressor was somewhat noisier than the other which portable measurements attributed to the fact that the air discharge piping on one compressor is lagged and the other is not. Since continuous manning of the compressors is not required, they are not considered a noise problem when functioning properly. The inboard venting during warmup is still a serious hazard, however.

Figure 30 compares one-third octave and dBA levels of ventilation system noise before and after the vent exhaust fan treatment was installed. The levels were measured dockside with only the vent system operating. The measurement location was the second deck level athwartships catwalk

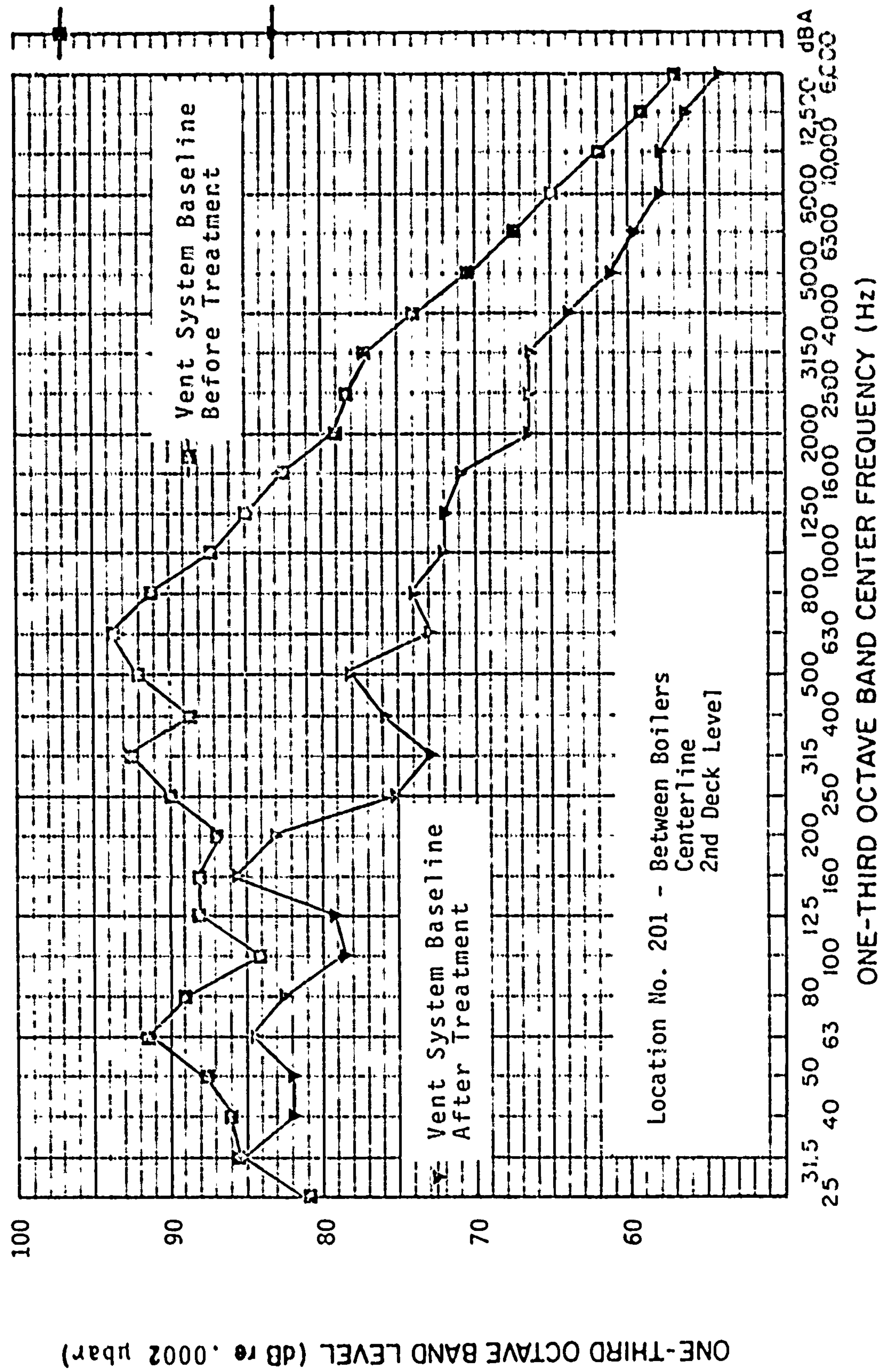


FIGURE 30: COMPARISON OF VENT SYSTEM NOISE BEFORE AND AFTER NOISE REDUCTION TREATMENT

between the boilers on the centerline, the location most seriously affected by the exhaust fan noise. The figure shows that exhaust fan noise has been reduced from 97 dBA to 83 dBA.

E. Assessment of Noise Reduction Achieved

While the discussion above described the results of the post-RAV trial in terms of noise levels achieved from the installation of the noise reduction treatment, it is also necessary to assess those results in terms of the reduction in hearing damage risk. The adequacy of the noise reduction achieved must also be judged as a basis for determining the need for more or less noise reduction. In order to make this assessment, the BUMED/OSHA hearing damage risk criteria must be referred to in more detail than the single member 90 dBA criterion.

The objective of the BUMED/OSHA criteria is to limit exposure of personnel to potentially hazardous noise levels such that hearing loss does not occur. Actually the achievement of that objective is somewhat complicated because the physiological impact of exposure to a given noise level is not the same for all individuals (reference 6). Therefore, the established criterion has been set on the basis that the probability of hearing loss for an individual will be acceptably low. This is the basis for the current limit of 90 dBA for eight hours exposure in a twenty-four hour period. In addition, the criterion states that for each 5 dB increase in noise level, the allowable exposure is halved. (e.g., The allowable exposure time to a noise level of 95 dBA is four hours in a twenty-four hour period.)

There is continuing debate among government and industry groups concerning the adequacy of protection to individuals provided by the current criterion (reference 6). The Environmental Protection Agency (EPA) is advocating a reduction in the eight hour exposure to 85 dBA and a reduction to 3 dB (versus 5 dB) in the doubling factor. It is impossible to predict the outcome of this debate, but the possibility exists of lower criteria at some future time.

As a basis for assessing the adequacy of the noise reduction achieved, a nominal workday in Navy ships underway must be examined. The nominal workday includes two-four hour watches and additional maintenance duties in the assigned division. While on watch, personnel typically spend three-fourths of the time at established watch stations and one-fourth of the time reading gauges, adjusting valves, etc., at various locations in the space. The additional duty time is spent in the assigned machinery space performing preventive and corrective maintenance. This nominal workday is assessed in the following discussions at 20 knot steaming conditions.

1.0 Engine Room

In the engine room there are two watch stations which are represented by measurement locations 1 and 2. The noise levels at these locations are 88 dBA and 89 dBA, respectively at 20 knots. Taking the higher noise level, the allowable exposure, using the 5 dB doubling factor, is nine hours in a twenty-four hour period. The watchstander, spending three-fourth's of his time at this watch station will receive two-thirds of his allowable noise exposure or six out of an allowable nine hours. The balance of the watchstanders allowable exposure would be reached by two hours exposure to noise levels of 92 dBA, a reasonable assumption based on the distribution of noise levels within the engine room. Thus, by standing two-four hour watches in the engine room, personnel will receive their full allowable exposure (i.e., equivalent to eight hours at 90 dBA); consequently, additional duty in the engine room would result in excess exposure and the risk of hearing damage.

The assessment just described for a ship speed of 20 knots, that is, no hearing damage risk if the workday is limited to two-four hour watches, essentially applies to speeds from 15 to 26 knots. Above 26 knots, the allowable exposure could be exceeded in one-four hour watch period. Below 15 knots the allowable exposure should not be exceeded during the entire nominal workday. Prior to the installation of the noise reduction treatment, allowable exposures were exceeded during two-four hour watch periods at 10 knots, the lowest speed at which measurements were taken.

In order to achieve the hearing damage risk criterion for the full nominal workday, at speeds above 15 knots, additional noise reduction will be required in the engine room. In order to achieve this reduction, noise produced by non-propulsion auxiliaries must be reduced in conjunction with further reductions in main reduction gear noise. In particular, as was pointed out in earlier reports, noise from the brine overboard eductors requires reduction. This reduction should be achieved by the SHIPALT which will replace the eductors with pumps. In addition, post RAV trial data indicates that the noise from fire pump No. 3 should be reduced. A relatively simple motor silencer should provide the needed reduction. As for the main reduction gear noise, further reduction will require expansion of the coverage of the close-coupled prototype treatment, notably to include the turbine sub-bases, or the use of an alternative treatment. Complete lagging of the lube oil piping will also be required as was originally planned in the RAV work package.

2.0 Fire Room

Using the rationale for determining allowable exposure as was used for the engine room, the measured noise levels in the fire room with the treatments installed indicate that allowable exposures would not be exceeded during the nominal workday at speeds through 21 knots. With only modest improvement from the correction of the uncompleted work on the forced draft blower duct treatment (i.e., the flexible boots), and with both exhaust fans treated in the same manner as the larger fan, the allowable exposure should not be exceeded for the nominal workday except at maximum speed. A compelling argument would be difficult to make for additional noise reduction because the frequency and duration of operations at maximum speed represents less than ten percent of the total operating time at sea.

Correction of the inboard venting of the Prairie/Masker compressors is required to eliminate this risk of hearing damage in the fire room during compressor warmup. Noise levels at some locations in the fire room were measured at 125 dBA during the thirty to sixty minute compressor warmup period. The highest noise level allowable for thirty minutes exposure in a twenty-four hour period is 110 dBA. Test team personnel present in the fire room for a short period during compressor warmups experienced temporary threshold shifts in their hearing. Until this problem is corrected, fire room personnel should wear ear plugs and ear muffs during compressor warmup.

F. Treatment Effectiveness

The bulk of this report is concerned with the noise reduction achieved by the treatments applied to FF 1082. In this section, the specific performance of the several treatments is investigated. The term, "treatment performance", is used here to mean the amount by which a treatment reduces the noise radiated from the treated area. This is not to be confused with the amount of overall noise reduction due to application of the treatment. The overall noise reduction may be somewhat less than the treatment performance because (1) all radiating surfaces could not be covered, (2) structural and/or acoustic flanking transmission paths limit the total reduction, or (3) other, untreated sources control the reduced noise levels.

1.0 Engine Room Treatment

The engine room treatment consisting of the close-coupled cladding applied to the main reduction gear case, the gear foundation, the main turbine foundations and enclosure of the condenser box could not be fully evaluated *in situ* aboard MONTGOMERY. Assessment of the cladding treatment must be in terms of both shipboard and laboratory test results.

The cladding treatment reduces radiated noise by three different mechanisms. Damping tile applied to the base structure reduces resonant modal vibration of the gear case, gear foundation, turbine foundations, and condenser box. The compliant layer of fiberglass and massive covering of lead vinyl acts as a spring-mass system effectively isolating vibration of the damped base structure from the radiating surfaces exposed to the air in the engine room, i.e., the sheet metal cover. In addition, the sheet metal cover is resiliently isolated from the base structure by the rubber isolators shown in Figure 11. Noise is also reduced by the fact that the sheet metal cover used to protect the treatment and for aesthetic purposes does not transduce surface vibration into airborne sound as readily as does the base structure. This latter point relates to matching of acoustic and structural wavelengths.

1.1 Laboratory Tests

Laboratory tests were performed at BBN using a flat, one-half inch thick steel plate approximately three feet by five feet. With the plate resiliently mounted in the wall between two reverberant rooms, electrodynamic shakers were attached to one side of the plate to set up a reverberant vibration field. Various treatments and combinations of treatments were applied to the undriven side of the test plate. In all cases, vibration measurements were made on the base plate and airborne sound measurements were made in the receiver reverberant room, i.e., the room on the treatment side of the plate. In some cases, vibration measurements were made on the outer surface of the treatment. From these measurements, transfer functions were generated. These transfer functions relate (1) the vibration on the base plate to vibration on the radiating surface of the treatment, (2) the vibration of the treatment surface to radiated sound power, and (3) the vibration on the base plate to radiated sound power. Structural reverberation times were measured to assess the significance of different types of damping treatments applied to the base plate. It should be noted that in this study, it is differences between vibration and/or acoustic levels that are of interest. Therefore, it was not important to duplicate the actual noise and vibration levels and spectra characteristic of the actual propulsion system.

- *Test Configurations*

Three test configurations representing the principal candidate treatments are discussed in this section. The generic cross-sections are shown in Figure 31. The first configuration (a) is a close facsimile to the treatment installed aboard the ship. The second configuration (b) included flexible elastomeric sheet insulation (1-in. thick Armaflex by Armstrong Cork Company) as the compliant member rather than the fiberglass blanket shown in configuration (a). The third configuration (c) also included the flexible elastomeric material, but with the outer sheet metal cover removed.

- *Structural Damping*

Effects of structural damping are best measured in terms of reverberation times. These reverberation times can be interpreted as loss factors, η, where the two parameters are related by the expression

$$\eta = \frac{2.2}{fT_{60}}$$

where f is the center frequency of the band of interest and T_{60} is the reverberation time. The change in plate damping due to adding damping tile to the plate is shown in Figure 32. The comparison is between the loss factor of the damped and

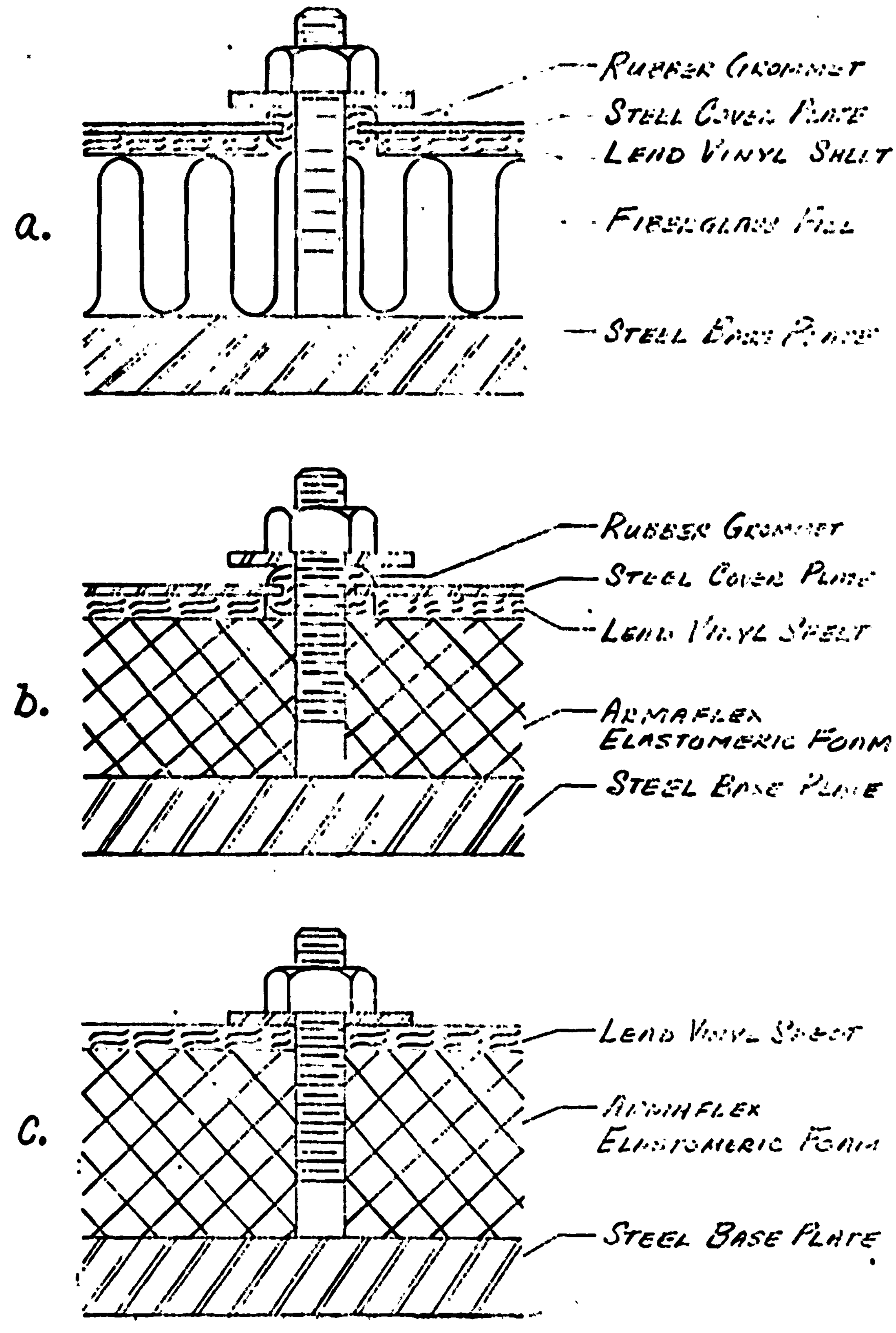


FIGURE 31: THREE TREATMENT CONFIGURATIONS TESTED IN LABORATORY

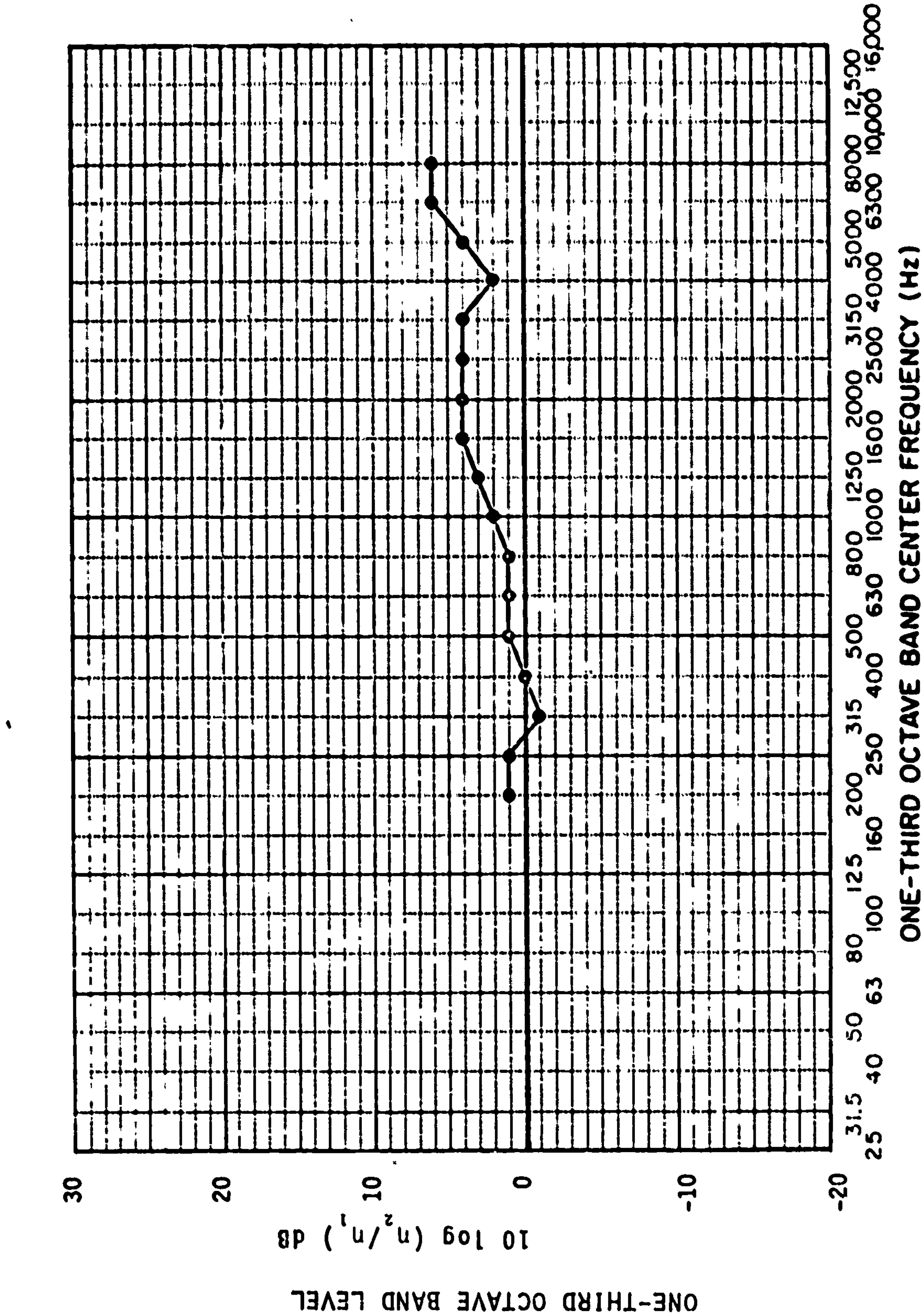


FIGURE 32: CHANGE IN LOSS FACTOR η DUE TO DAMPING TILE
(η_1 undamped, η_2 damped)

undamped plate plotted on a logarithmic scale. Thus, the reductions of up to 6 dB implied by Figure 32 are reasonable engineering estimates of the effects of damping in all three of the treatment configurations. The damping treatment tested in the laboratory is the same type as used on the gear casing. In these tests, the base plate was heated to approximately 130°F to simulate the gear case operating temperature.

- *Vibration Isolation*

Configuration (a) of Figure 31 duplicates the gear treatment with the exception that the sheet metal cover plate in the laboratory is resiliently isolated from the studs on the base plate by grommets instead of by the isolation mounts shown in Figure 11. As in the other tests, the base plate was heated to approximately 130°F. Vibration (acceleration) levels were measured at several positions on both the base plate and on the sheet metal cover. The difference between average vibration levels of base plate and cover are plotted as a function of frequency in Figure 33. The values in Figure 33 represent an engineering estimate of the expected vibration isolation of the gear case treatment. Similar results are anticipated for the treatment applied to the gear and turbine foundations.

Values of vibration isolation measured in the laboratory on treatment configuration (b) are also shown in Figure 33. This figure indicates that in the mid-frequency range, the vibration isolation afforded by the Armaflex material is generally a few dB less than the vibration isolation demonstrated by the fiberglass used in configuration (a). This appears to be due to greater stiffness of the elastomeric foam.

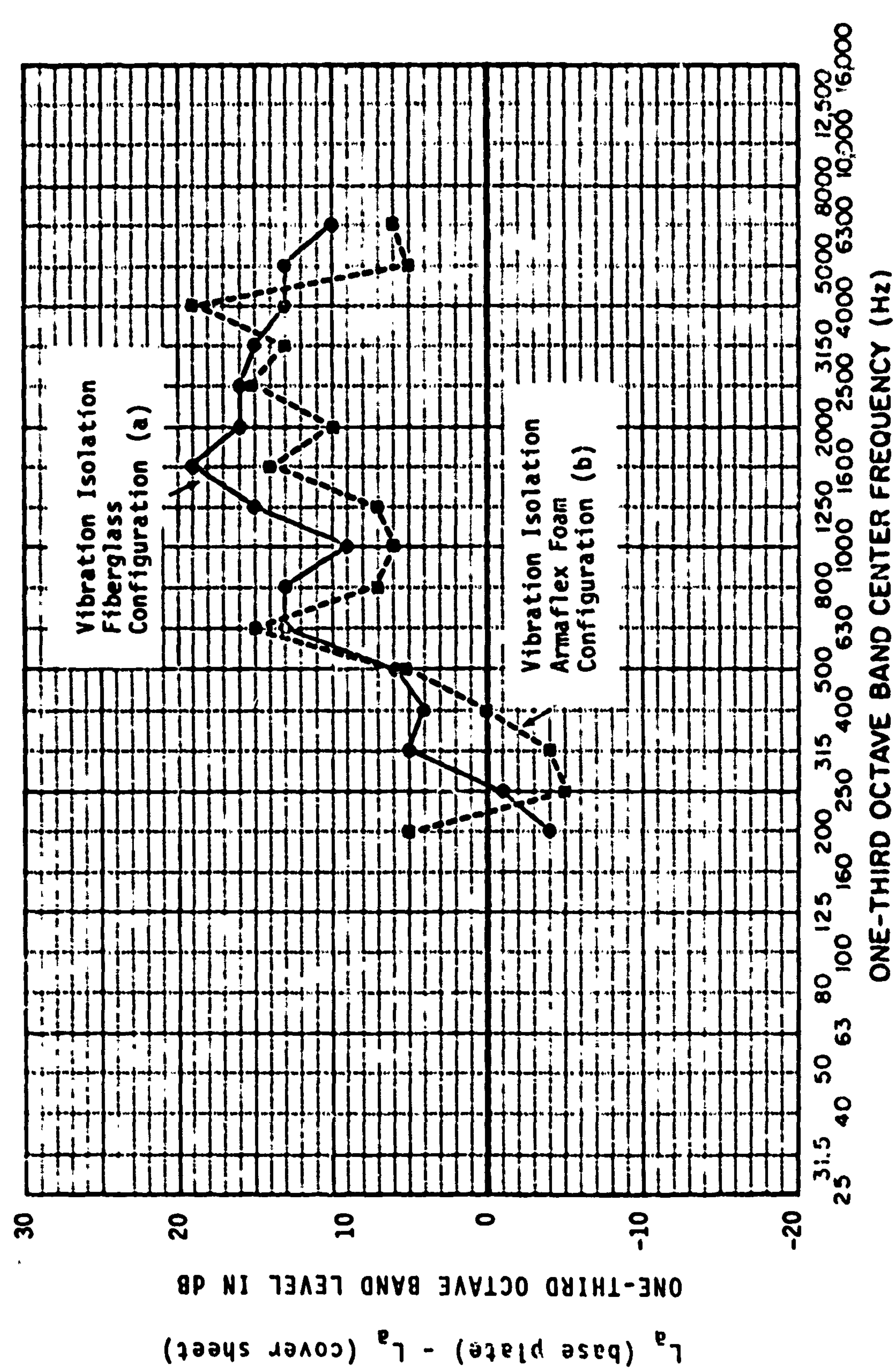


FIGURE 33: VIBRATION ISOLATION OF TREATMENT TEST CONFIGURATIONS (a) AND (b) (AS SHOWN IN FIGURE 31)

Due to the flexible nature of the lead-loaded vinyl sheet, it was not possible to obtain vibration measurements that meaningfully reflect the vibration isolation characteristics of the elastomeric insulation in the absence of a sheet metal cover plate configuration (c).

Results of these tests mean that if the sheet metal cover plate were as efficient a radiator of sound as the base plate, the total radiated sound power from the fully treated plate would be less than that radiated from the damped base plate by the amounts shown in Figure 33 for configurations (a) and (b). In fact, the radiation properties of the sheet metal cover (and the base lead vinyl) are somewhat different from those of the base plate.

- *Radiation Efficiency*

Radiation efficiency, σ_{rad}, defined mathematically by

$$\sigma_{rad} = \frac{\Pi}{\rho c A \langle v^2 \rangle}$$

is the ratio of sound power radiated (per unit surface area) to the vibration of that surface. In the definition above, Π is the total radiated sound power, A is the total radiating surface area, $\langle v^2 \rangle$ is the space-averaged mean-square velocity of the surface vibration, and ρc is the specific acoustic impedance of air.

Laboratory measurements were made of the sound power radiated from the untreated base plate and the vibration of the plate. Similar measurements were made comparing vibration of and sound radiation from the cover plate of configurations (a) and (b) in Figure 31. From these measurements, radiation efficiencies of the base plate and the cover sheet were calculated. The differences between these two values are plotted on a logarithmic scale in Figure 34.[1]

Figure 34 indicates that the sheet metal cover plate is a much less efficient transducer for converting vibrational energy into airborne sound than is the base plate. In the mid-frequency range, sound radiation per unit of vibration is 10-20 dB less for the cover plate than for the base plate. This is consistent with elementary theoretical considerations. The effect of replacing the fiberglass in configuration (b) with Armaflex does not significantly change the radiation efficiency of the sheet metal cover. Effects of cover plate isolation are more important.

- *Combined Laboratory Results*

When the damping, vibration isolation, and radiation efficiency results of the laboratory tests are combined, the total treatment performance shown in Figure 35 is calculated. The values shown here represent the total "treatment performance" expected of the close-coupled cladding shown in Figure 11 and the treatment applied in the engine room. These results are borne out in comparisons of radiated sound power and base plate vibration. Clearly the major effects are those of the vibration isolation and changes in radiation efficiency.

Figure 35 also shows the anticipated total noise reduction that would be achieved using configuration (b) in which elastomeric insulation is substituted for fiberglass as the compliant

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[1]Insufficient signal-to-noise ratios limit the base plate data to the frequency range above 315 Hz. Data obtained show excellent agreement with simple plate theory, therefore, theoretical results are used in deriving the values shown in the 200-315 Hz frequency bands of Figure 34.

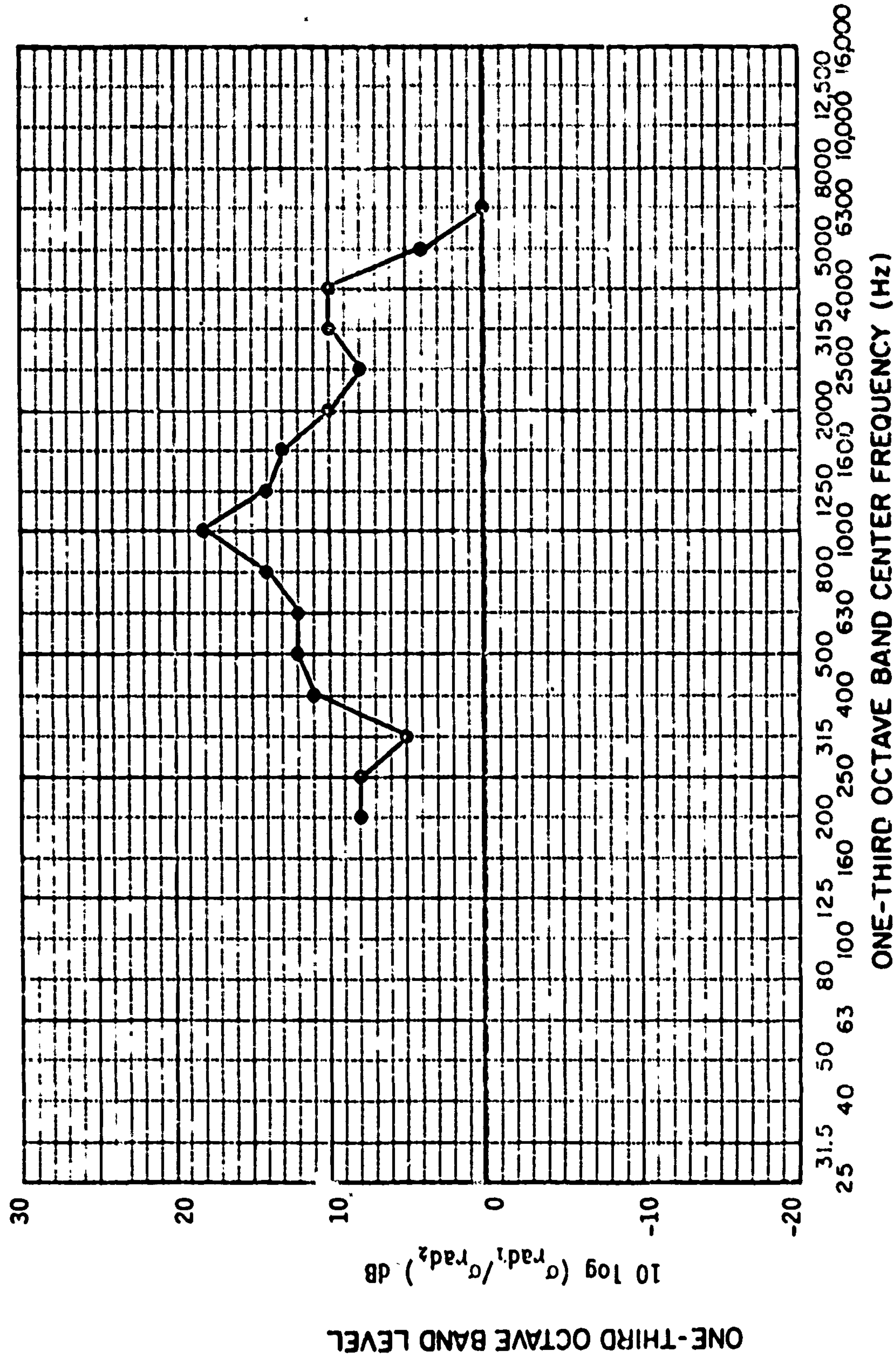

FIGURE 34: CHANGES IN σRAD FOR TEST CONFIGURATION (a) AND (b) (AS SHOWN IN FIGURE 31)

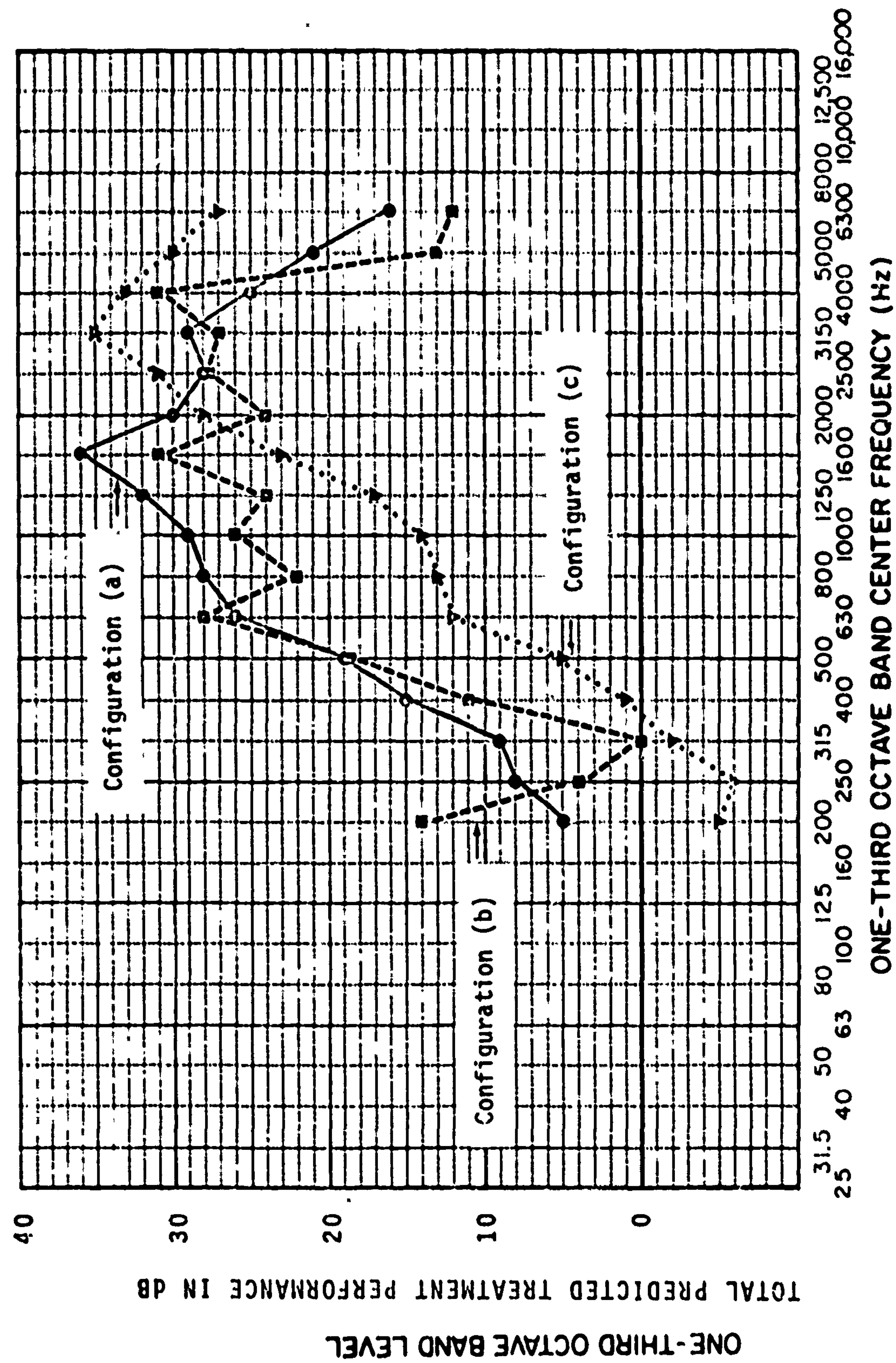

FIGURE 35: PREDICTED NOISE REDUCTION PERFORMANCE OF TEST CONFIGURATIONS (a), (b), and (c) (AS SHOWN IN FIGURE 31)

layer. This curve in Figure 35 illustrates that the decreased vibration isolation afforded by the elastomeric material degrades the overall performance of this treatment compared to that used in MONTGOMERY.

The third curve in Figure 34 represents the treatment performance expected of configuration (c) of Figure 31. The values shown in this curve are derived from comparison of sound radiation and base plate vibration with and without the treatment in place. In this case it is not possible to separate the effects of vibration isolation and radiation efficiency modification. It is seen that although the maximum performance of configuration (c) is comparable to that of configuration (a), this maximum occurs at a somewhat higher frequency for configuration (c). Below 2000 Hz, the performance of configuration (a) is 10-15 dB better than that of configuration (c).

1.2 Shipboard Measurements

Because of the complex and extended nature of the shipboard installation, it was not possible to evaluate the engine room treatment performance in the detail possible in the laboratory. The only practicable measure of the treatment performance is a composite evaluation of damping and vibration isolation.

Although no measurements were made of the radiation efficiency of the treatment as applied in the engine room of MONTGOMERY, there is no reason to expect the radiation efficiency of the shipboard installation to be significantly different from the radiation efficiency measured in the laboratory tests.

- *Damping and Vibration Isolation*

In the post-RAV sea trial, vibration measurements were made on the treatment cover plate at several positions corresponding to measurements on the untreated gear case. These measurements were made on the large flat surfaces representative of the major sound radiating areas. Comparing the two sets of levels indicates the combined effects of gear case vibration reduction by damping and vibration isolation by the compliant layer and the massive layer of lead vinyl and the sheet metal cover.

The average differences between vibration levels on the cladding cover and on the untreated gear case measured at several positions are shown in Figure 36. For reference, the vibration isolation measured in the laboratory are also shown in Figure 36. Two observations should be noted. First, there is a wide variation in the effectiveness depending on where transducers were located on the main reduction gear. This is not unexpected because of the complex nature of the coupling between the cover sheet and the gear case. In particular, the effects of edge terminations of the cover plate are much different in the shipboard installation than in the laboratory. Second, there is reasonably good agreement between the laboratory results and the performance of the shipboard installation. This suggests that the laboratory test results accurately represent a measure of the shipboard performance achievable over the frequency range of interest. The performance of the shipboard installation may appear to be better than that measured in the laboratory because of better vibration isolation of the cover. The overall results in the shipboard configuration confirms the notion that the laboratory test procedure is an appropriate method for (1) predicting the effectiveness of treatments in the shipboard environment and (2) rank ordering the performance of different types of cladding treatments.

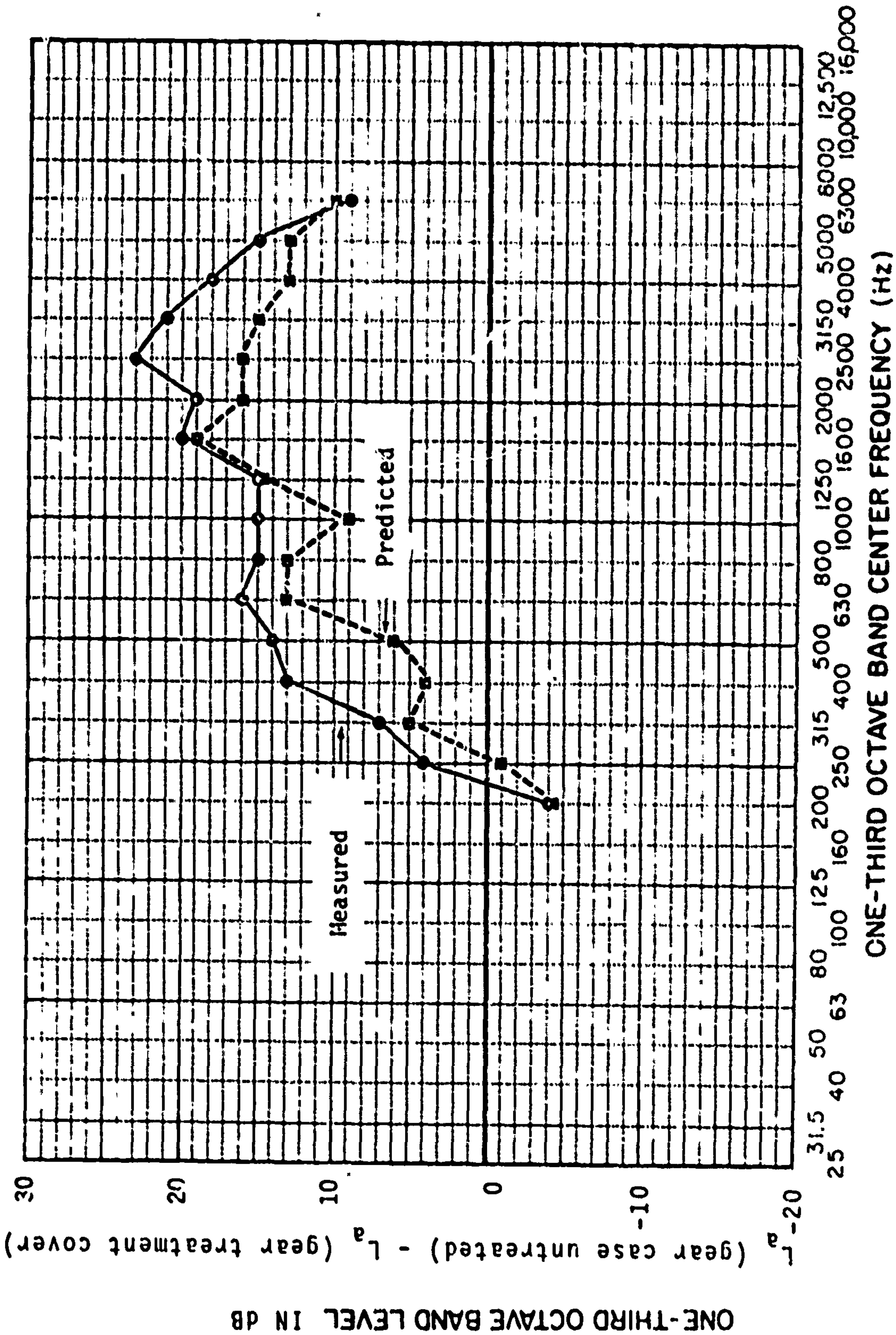

FIGURE 36: COMPARISON OF VIBRATION ISOLATION MEASURED ABOARD SHIP AND PREDICTED FROM LABORATORY TESTS

2.0 Fire Room Treatment

Fire room treatments consisting of the forced draft blower duct cladding and the ventilation exhaust fan palliatives are closely related and cannot be easily evaluated independently. This is because the ventilation exhaust fans appear to be significant flanking paths for forced draft blower noise in the fire room.

- *Exhaust Fan Treatment Performance*

Comparison of ventilation exhaust fan noise at the center position at the second deck level before and after treatment is an appropriate measure of the fan noise reduction achieved on MONTGOMERY. These values of reduction are shown in Figure 30. More detailed analysis is required to separate the performance of the fan relocation and duct lining treatment from the performance of the barrier treatment.

Tests were performed on MONTGOMERY after treatment and on DOWNES, primarily to quantify the forced draft blower flanking path. The arrangement of forced draft blowers and fire room exhaust fans on DOWNES is sufficiently similar to that on MONTGOMERY that comparison of the two sets of measurements is considered an adequate measure of the effectiveness of the treatment applied to MONTGOMERY. Since the forced draft blower noise was the subject of interest, the evaluation was performed only in the 2500 Hz and 4000 Hz one-third octave bands where the forced draft blower tones are usually found.

These test results indicate that the treatment involving fan relocation increases the transmission path attenuation by 8 and 7 dB in the 2500 and 4000 Hz bands, respectively. Except at a position directly beneath the lined barrier, the increased attenuation due to the inverted "top hat" is minimal, nominally 1 dB at the high frequencies.

It should be noted that the barrier treatment applied to the so-called "small vent" exhaust fan is not the design recommended. The installed treatment does not effectively block line of sight from potentially manned locations into the fan bellmouth as was intended in the original recommendation. Performance of the treatment applied to the "large vent" fan is judged to be quite acceptable and is in good agreement with the expected effectiveness.

3.0 Forced Draft Blower Treatment

It was not possible to perform pre-installation and post-installation measurements of acoustic transmission loss though the walls of the forced draft blower ducts. Therefore, no firm evaluation of the lagging treatment can be given. A measure of the treatment performance can be inferred from reduction of the forced draft blower tones at various microphone locations provided account is also taken of the flanking paths through the fire room ventilation exhaust fans. Estimated values of the effectiveness of the lagging treatment applied to the forced draft blower ducts are on the order of 10-15 dB in the frequency range 2000-6300 Hz where forced draft blower tones are significant.

Noise measurements taken with portable instruments indicate that incomplete closures of the lead vinyl boot sections, particularly around penetrations for damper counterweights and grease fittings, act as noise leaks. It is not known precisely how much this deficiency degrades the performance of the treatment as regards noise at manned or potentially manned locations; however, it is an installation defect that can be easily remedied.

It is interesting to note that on USS DOWNES, the forced draft blower ducts are already covered with a lagging treatment. Although this treatment may reduce acoustic radiation from the treated surface areas, maesurements at the fixed microphone locations indicate that there is no significant overall reduction of blower noise due to the treatment used on DOWNES. This may be because most forced draft blower noise is transmitted through the untreated expansion joints which are constructed of very thin metal.

III. INTRA CLASS SIMILARITY TESTS

To insure that the noise characteristics of ELMER MONTGOMERY were not atypical of the FF 1052 class, airborne noise trials were conducted on a second ship in the class. Differences within the class which could alter airborne noise levels in the machinery spaces include major machinery produced by different manufacturers and construction practices produced by different building yards. Significant differences in space and machinery arrangements were not expected and none were found.

A. USS DOWNES Trial Results

USS DOWNES (FF 1070), based in San Diego, was designated as the ship for the intra class similarity tests. As was the case with the post-RAV trial on ELMER MONTGOMERY, noise tests were planned for DOWNES which would replicate measurement locations and machinery conditions as nearly as possible for comparison with pre-RAV trial results from ELMER MONTGOMERY.

Dockside and underway airborne noise tests were conducted in DOWNES during the period 15 through 24 January 1976. Minor difficulties were encountered because of out-of-commission machinery which could not be tested, and the maximum speed achievable was 26 knots; however, overall trial objectives were achieved. Ship to ship differences and trial results relating to the individual machinery spaces are described below.

1.0 Engine Room

A major reason for selecting DOWNES was that it was equipped with a main reduction gear of a different manufacture than MONTGOMERY. Variations in the routing of piping resulted in the brine overboard eductors being in a slightly different location in DOWNES. No other significant differences were noted; however, the fire pump (No. 3) was inoperative and could not be tested.

Measurements were conducted at the same locations as described previously on ELMER MONTGOMERY and at the same speed increments. The measured A-weighted noise levels are shown in Table 5, side-by-side with comparable measurements on the MONTGOMERY pre-RAV trial. A remarkable similarity in the measured levels can be seen from the table. Differences in the measured levels, where they occur, are typically one to two dB which is essentially the expected range of repeatability of measurements. The conclusion is that the two engine rooms are essentially the same from an airborne noise standpoint.

While the overall magnitude of the noise levels on DOWNES and MONTGOMERY were very similar, the spectral characteristics of the main reduction gear noise were different. One-third octave levels, measured at Microphone Location No. 3, on the lower level just outboard of the main reduction gear on the starboard side, are shown in Figure 37 for both ships. Below 630 hertz, the levels, while not the same in amplitude, have essentially the same spectral shape. Above 630 hertz, however, there is a distinct difference. On DOWNES there is one distinct peak produced by the second reduction mesh. On MONTGOMERY there are two peaks, of which one corresponds to the second reduction mesh which is lower in frequency than DOWNES because of a difference in the number of teeth on the second reduction gear set although the gear ratios are the same. The second peak on MONTGOMERY

TABLE 5

COMPARISON OF ENGINE ROOM NOISE LEVELS IN dBA
USS ELMER MONTGOMERY AND USS DOWNES
(WITHOUT TREATMENT)

MEASUREMENT LOCATION	MIKE No.	SHIP SPEED IN SHAFT RPM						
		80	100	120	140	160	180	200
*ML - Workbench By A/C Plant #2	1	85/84	87/87	39/89	88/87	92/89	92/90	94/91
*ML - Log Desk by Evaps	2	90/89	91/90	91/90	91/90	92/93	93/91	93/92
LL - Starboard - Outboard MRG	3	96/93	95/91	97/94	95/95	101/99	100/96	102/98
ML - Port - Outboard MRG	5	--/88	91/92	91/92	90/91	97/96	--/94	--/96
LL - Port - Outboard MRG	7A	--/90	--/91	--/91	--/93	--/96	--/96	--/97
LL - Fwd - Between Fire P. & Cond.P	12	--/95	95/95	--/94	--/96	98/98	98/97	99/93
LL - Fwd - Between Cond. & Circ P.	13	95/93	94/94	95/95	94/95	97/99	99/99	99/100
UL - Center of MRG	14	--/87	87/91	91/89	--/89	94/93	--/94	97/94
ML - Fwd - By Main Air Ejector	17	91/91	92/91	91/92	90/92	93/95	93/95	94/95

LL - Lower Level   ML - Middle Level   UL - Upper Level   *Manned Locations

NOTE: Slashed numbers in columns above represent MONTGOMERY/DOWNES noise levels.

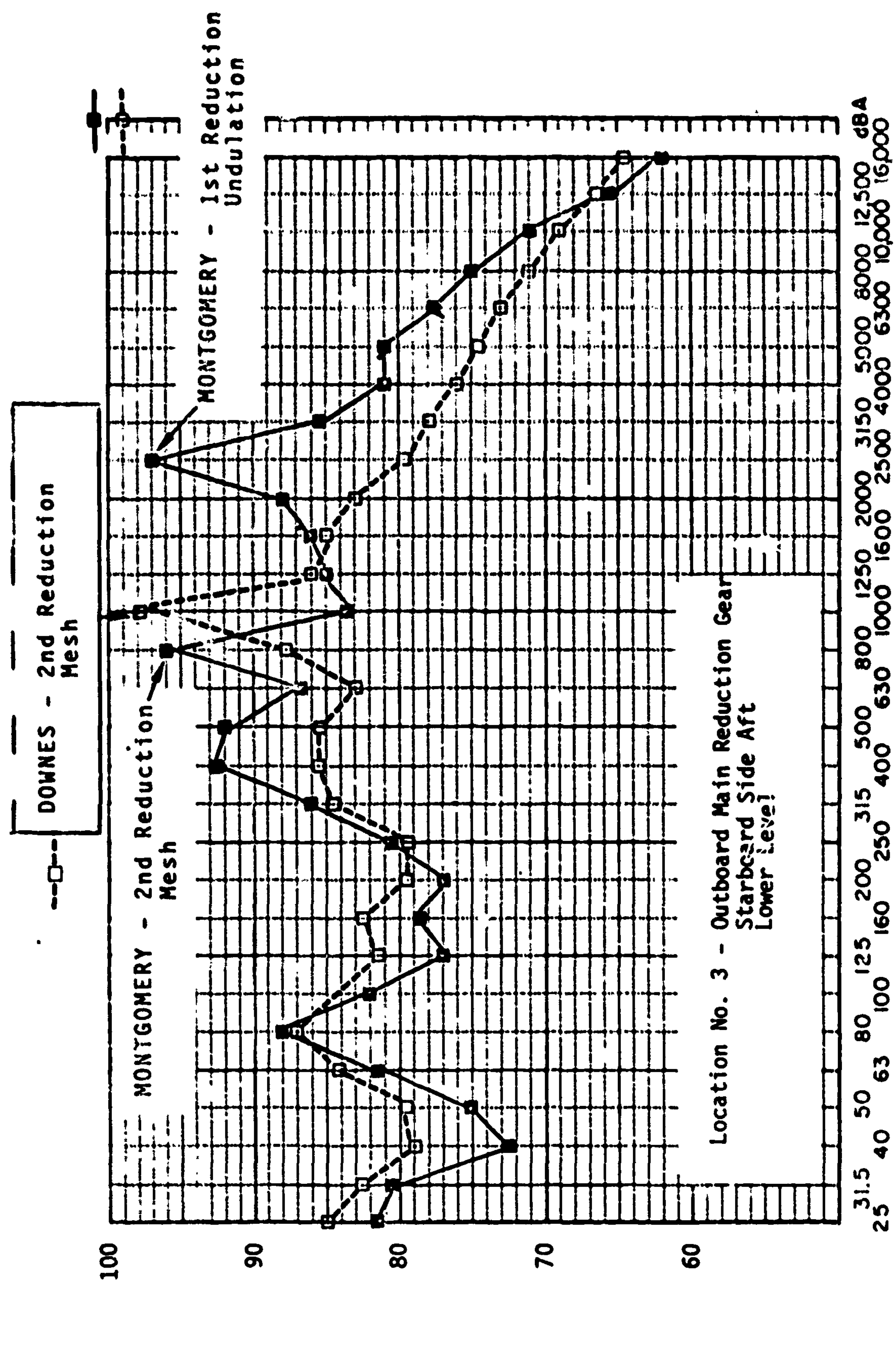

FIGURE 37: COMPARISON OF MAIN REDUCTION GEAR NOISE ON USS ELMER MONTGOMERY AND USS DOWNES AT 160 SHAFT RPM

has been identified as undulations in the first reduction gear. These undulations are the result of manufacturing methods which sometimes cause uneven tooth contact and tooth wear. The magnitude of this tone on MONTGOMERY, relative to the magnitude of the second reduction mesh amplitude, suggests that the undulations may be causing excessive wear and the gear should therefore be inspected.

The differences in the A-weighted levels shown in Figure 37 are attributable almost exclusively to the gear tones just described. However, the magnitude of the difference in level does not suggest that different noise control methods are needed or necessarily desirable.

2.0 Fire Room

Machinery differences noted in the fire room were that the boilers were of different manufacture. Construction differences included a lagging, similar in appearance to that used on steam piping, installed on the forced draft blower ducts. Also, the vent for the Prairie/Masker compressors did not terminate in the fire room. Prairie/Masker compressor 1B was not operational and could not be tested.

Although the forced draft blower rooms are unmanned spaces, a difference was noted between the two ships. In DOWNES, the forced draft blowers were partially enclosed with removable covers. However, noise measurements taken with portable sound level meters in both ships showed no appreciable difference in noise levels in the forced draft blower rooms.

The results of measurements taken at various ship speeds and at the same microphone locations described earlier for the MONTGOMERY trials are shown in Table 6 side-by-side with comparable results from MONTGOMERY measurements taken before the noise reduction treatment was installed. Care must be taken in drawing conclusions solely from the data in Table 6 because due to uncontrollable circumstances, it was not possible to exactly duplicate machinery lineups in every test. In particular, differences in lineups of forced draft blowers and main feed pumps were determined to account for the significant differences in noise levels between the two ships.

Machinery lineups were most nearly duplicated during the 200 RPM test run where all four forced draft blowers were on the line. At the 200 RPM speed, the data show that noise levels at some locations were three to four decibels lower than on MONTGOMERY, possibly indicating some benefit from the lagging of the forced draft blower ducts. More benefit in noise reduction might have been expected from the duct lagging on DOWNES; however, the expansion joints and damper areas were not covered which demonstrates the need for maintaining the acoustic integrity of noise control treatment if serious compromise to the treatment is to be avoided. These results on DOWNES are also considered a demonstration of the importance of completing the finish work on the flexible boots on MONTGOMERY forced draft blower duct treatments.

On DOWNES the No. 2 fire pump in the fire room was noisier than on MONTGOMERY, producing noise levels above 90 dBA at a distance of approximately six feet. The variability in noise from these units argues for noise control,

TABLE 6

COMPARISON OF FIRE ROOM NOISE LEVELS IN dBA
USS ELMER MONTGOMERY AND USS DOWNES
(WITHOUT TREATMENT)

MEASUREMENT LOCATION	MIKE No.	SHIP SPEED IN SHAFT RPM						
		80	100	120	140	160	180	200
*LL - Between Boilers Starboard Side	81A	88/87	88/86	88/90	88/93	90/90	93/91	95/94
LL - Near P/M Comp #1B	82	87/82	87/83	87/88	87/86	88/90	90/87	92/94
UL - Near Main Feed Pump #1C	88	92/91	91/92	93/99	92/95	94/98	95/94	100/96
LL - Near Fire Pump #2	104	88/91	88/93	88/95	88/97	94/97	92/97	94/99
*UL - At Workbench Port Side	155	86/88	87/88	87/91	87/97	93/91	93/94	93/96
UL - Between ladders Port Fwd	156	85/82	86/82	87/83	86/83	94/83	92/90	97/95
UL - Between Boilers on Centerline	157	91/91	92/92	92/97	92/93	99/98	100/96	102/99
UL - Near Main Feed Pumps #1A & 1B	158	86/90	87/91	87/91	87/91	90/95	93/96	96/97
2D - Between Boilers on Centerline	201	95/92	95/92	96/97	97/96	98/97	100/97	103/100

LL - Lower Level UL - Upper Level 2D - 2nd Deck Level *Manned Locations

NOTE: Slashed numbers in columns above represent MONTGOMERY/DOWNES Noise Levels.

particularly when the reduction needed can probably be provided by a relatively simple and inexpensive motor silencer.

The noise levels of ventilation system noise on DOWNES were somewhat lower than on MONTGOMERY. However, noise levels in the range of 90 dBA from the ventilation system operating alone still argues for noise control of the vent exhaust fans as part of a class noise reduction package.

The most significant difference in noise levels concerned the venting of the Prairie/Masker compressors. Because the compressors were vented out of the fire room, the noise levels during warmup of the compressors was no higher than during normal operation with the compressors feeding the emission systems. Noise levels adjacent to the compressor reached 90 dBA, essentially the same as on MONTGOMERY. On MONTGOMERY, the lagging on the piping of one compressor had been removed, apparently for some corrective maintenance, and the noise levels near that compressor were higher, indicating the need to replace such treatment to prevent the inadvertent creation of a new noise problem.

3.0 Auxiliary Machinery Room No. 1

Only minor differences were noted in this space between the two ships. For example, the log desks were not located in the same place. The results of measurements conducted underway with normal steaming machinery lineups showed noise levels essentially identical to those measured in MONTGOMERY. Therefore, from a class standpoint, it is concluded that noise reduction will not be required in this space from a hearing damage risk standpoint.

B. Summary of Differences within the FF 1052 Class

On the basis of the trials conducted in ELMER MONTGOMERY and DOWNES which represent the known differences within the FF 1052 class, no significant differences in noise characteristics were found which would preclude a single noise control approach for the entire class. The only exception to this is the venting of the Prairie/Masker compressors. Noise levels produced in the fire room during compressor warmup when the compressors are vented inboard are hazardous even though they are infrequent. This problem should be corrected on the ships in the class where this condition exists.

Measurements conducted aboard USS DOWNES argue for treatment of another noise source, the fire pumps. While pre-RAV measurements in ELMER MONTGOMERY identified these units as a potential problem, measurements in DOWNES demonstrated that the fire pumps alone can produce noise levels in excess of 90 dBA. Even when the source level of these units is below 90 dBA, they maintain a background level sufficiently high that the full potential of noise reduction applied to other sources is not fully realized, particularly at low and nominal cruising speeds which are typical of a large percentage of the operational life of the ship. Inclusion of noise reduction for the fire pumps in manned spaces would increase the cost of the noise control package probably less than one percent. It certainly would cost less to include this added treatment in a class package than to determine its need on an individual ship basis.

There are sufficient differences in the physical configuration of the two types of main reduction gears to require two designs for installation of a close coupled treatment. Other types of noise control, such as enclosures, which do not conform as closely to the gear casing could be expected to accommodate these differences in a single design.

IV. CONCLUSIONS

This program represents the first comprehensive concerted effort to reduce airborne noise in active surface ships in order to achieve hearing damage risk criteria in machinery spaces. New insights have been gained concerning the characteristics of shipboard machinery noise as well as the approaches to control it, and noise control approaches have been subjected to comprehensive performance tests for the first time. These efforts, and the experience they provided, have resulted in the formation of conclusions concerning control of shipboard machinery noise in general and treatment of such noise in the FF 1052 class of ships.

A. Noise Control Criteria

In the past, when noise control criteria have been specified for airborne noise in machinery spaces, the basic objective has been the avoidance of hearing loss. To achieve this objective, a noise category, defined by OPNAV Instruction 9330.5, has been specified. Usually a Category D is specified for machinery spaces which is defined as a set of octave band levels. Noise Category D derives from and is essentially equivalent to 90 dBA, which is the BUMED/OSHA noise limit for eight hours exposure in a twenty-four hour period.

There is a basic difficulty with this Category D, or even the 90 dBA criteria, in that both relate to an industrial eight hour workday and employment lifetime which are not typical of the shipboard work environment or Navy career duration. Therefore, the hearing loss risk probability associated with the BUMED/OSHA 90 dBA criteria may not be achieved in the shipboard environment.

Another factor in the problem is the practicality of achieving the 90 dBA criterion at every location in a machinery space. If noise levels are higher than these criteria at some locations where personnel are required to be at short intervals during the course of the workday, the allowable noise dose is received at a faster rate and the criteria would be exceeded even though the bulk of the workday is spent in locations meeting the 90 dBA criterion.

It is concluded, therefore, that noise levels in machinery spaces that meet Category D and/or 90 dBA will not necessarily satisfy the intent of those criteria with respect to hearing loss. A more definitive criteria is believed to be needed which considers a realistic description of the activities and duration of the shipboard workday, as well as the career duration of Navy personnel exposed to shipboard noise. Studies should be undertaken to establish new, realistic criteria for shipboard machinery spaces.

B. Noise Reduction Limitations

The amount of noise reduction achievable in a given machinery space is dependent upon three factors:

1. The number of noise sources treated;
2. The type of noise reduction treatment used; and
3. The composite noise level of the untreated noise sources.

The composite noise level of the untreated sources establishes a floor or baseline beyond which further reduction is not possible regardless of the performance of the treatment applied to the treated sources. Above this baseline, the achievable noise reduction is a function of the acoustical performance of the treatments applied.

Because of the relative cost of the treatment for the main reduction gear, it would be advantageous from a cost standpoint to reduce the baseline level by treating additional noise sources which control the baseline level. A SHIPALT is under development which will replace the brine overboard eductors. In addition, relatively inexpensive motor silencers for the fire pumps should reduce baseline levels further to realize a higher payoff in gear treatment effectiveness.

C. Alternative Noise Control Approaches

In the establishment of an overall noise control improvement package for machinery spaces in FF 1052 class ships, several alternatives are worthy of consideration in addition to the treatments tested in ELMER MONTGOMERY. These alternatives are discussed below as they apply to the individual machinery spaces.

1.0 Engine Room

In the engine room the only sources treated in ELMER MONTGOMERY were the main reduction gear, its foundation and the main turbine foundations. After treatment of these sources, baseline levels approaching 90 dBA remained in some locations. This approach makes it very difficult to achieve a goal in the range of 90 dBA from the gear treatment alone.

Installation of the SHIPALT to replace the brine overboard educators will alleviate this high baseline problem somewhat leaving the fire pump as the most significant untreated source. Treatment of the fire pump is simple and inexpensive and would further alleviate the baseline problem and result in better reduction of the composite underway noise levels.

The close-coupled composite treatment as installed in ELMER MONTGOMERY performed as expected by reducing noise levels to below 90 dBA at continuously manned watch-stations at all except maximum speeds. However, at some locations, noise levels remain above 90 dBA, even at low ship speeds. If further noise reduction is desired, the treatment coverage must be expanded to cover the turbine sub-bases.

An alternative approach to controlling the main engine and gear noise is a noise enclosure. Such an enclosure recently demonstrated better noise reduction on USS SOUTH CAROLINA than was achieved with the close-coupled treatment on ELMER MONTGOMERY (reference 9). The experience gained on ELMER MONTGOMERY and SOUTH CAROLINA does not provide a clear answer to the relative merits of the two types of noise control approaches. Design and installation difficulties on both ships resulted in distorted cost experience. The enclosure was fabricated in the ship and assembled in place on the SOUTH CAROLINA, whereas the close-coupled treatment required considerable cutting and fitting in place on ELMER MONTGOMERY. The enclosure should be less labor intensive and less susceptible to variations in craftsmanship although this supposition was not clearly proven by experience on the two ships. The weight (per unit area) of the enclosure on SOUTH CAROLINA was about one-third that of the close-coupled treatment on ELMER MONTGOMERY, thus providing a potential weight advantage for the enclosure. Both the enclosure and close-coupled treatment designs are sensitive to machinery maintenance requirements which should be carefully implemented to minimize the maintenance impact. The subsequent experience of the two ships with regard to the maintenance aspect of the treatments would be useful inputs to the selection of alternative treatments as well as design optimization.

2.0 Fire Room

Two separate approaches were used in the two ventilation exhaust fans in the fire room. The treatment of the larger fan which included relocating the fan in the uptake space proved to be the more effective approach by a comfortable margin. It is believed that treatment of larger fan had a slightly higher cost but was offset by the marked improvement in performance.

In the noise tests in USS DOWNES, the noise baseline in one portion of the fire room was held above 90 dBA by the fire pump. Comparable noise levels in MONTGOMERY were only slightly below 90 dBA. A simple and inexpensive motor silencer for the fire pump would ensure baseline levels well below 90 dBA in this portion of the fire room.

The treatment on the forced draft blower ducts performed to expectations. While there are other methods of duct lagging, none appear to offer any appreciable savings in cost or improvement in performance.

V. RECOMMENDATIONS

Summarized in this section are the recommendations comprising a noise control package for the FF 1052 class. Also outlined is a recommended approach to extend the hearing conservation program to other ship classes.

A. FF 1052 Class Improvements

The recommended class improvement package for the FF 1052 class is comprised of noise reduction treatments for the main reduction gear case and foundation, foundation and sub-base of main steam turbines, forced draft blower ducts, fire room vent exhaust fans, brine overboard eductors, fire pumps in the engine and fire rooms and Prairie/Masker compressor vents. The treatment for the brine overboard eductors is already scheduled in the form of a SHIPALT to replace the eductors with pumps. The recommended treatments for the other noise sources are discussed below.

1.0 Main Reduction Gear Treatment

The treatment as installed and tested on ELMER MONTGOMERY covered the main reduction gear, its foundation and the foundations for the main turbines. On the basis of the MONTGOMERY tests, it is recommended that the coverage be extended to include the turbine sub-bases as well as lagging of the lube oil piping which was planned for but not accomplished.

Because of the cost and performance of an enclosure type treatment recently installed and tested on USS SOUTH CAROLINA, it is recommended that the design for a similar type enclosure for FF 1052 class be evaluated as an alternative to the close-coupled treatment. It is estimated that it would cost approximately $10,000 for a shipyard to develop a design and cost estimate to provide a basis for comparison with the close-coupled treatment. Because of the number of ships in the FF 1052 class, any per ship savings represented by the alternative enclosure is multiplied forth-five times if it is applied to the remaining ships in the class.

2.0 Forced Draft Blower Ducts

It is recommended that all ships of the class receive the forced draft blower duct treatment as installed on ELMER MONTGOMERY consisting of a fiberglass blanket covered with a thin steel sheath and using flexible boots in lieu of the steel sheath over expansion joints and damper sections. Additional installation details should be designed for the flexible boots to ensure that the acoustical intensity of the treatment is maintained from boiler surface to deckhead. As was done on ELMER MONTGOMERY, the same treatment is recommended for the lighting-off blower ducts as well.

3. Fire Room Vent Exhaust Fans

It is recommended that both exhaust fans be treated in the same manner as was the larger fan in ELMER MONTGOMERY. This treatment consisted of relocating the fan in the uptake space from a vertical to a horizontal position and reconnecting to the original deck collar with a straight duct section and ninety degree elbow, both acoustically lined. This approach will eliminate the need for the top hat type baffle that was installed on the smaller fan in ELMER MONTGOMERY.

This change from the MONTGOMERY installation will result in a significantly improved treatment performance at an expected slight increase in cost.

4.0 Fire Pumps in Engine and Fire Rooms

While these units were not treated in ELMER MONTGOMERY, tests on the DOWNES indicated noise levels in excess of 90 dBA can be expected. It is, therefore, recommended that these units be provided with relatively simple motor silencers. Silencers of this type are commercially available for approximately $300 per unit.

5.0 Prairie/Masker Compressor Vents

In ships of the class in which the output of the Prairie/Masker compressors is vented into the fire room during compressor warmup, it is strongly recommended that the vent be modified. The design for a modification to this vent was developed by the shipyard during the MONTGOMERY RAV, but was not installed due to schedule and funding limitations. While the design effort on this modification are complete, installation cost estimates have not been obtained from the shipyard.

B. Recommendations for Other Ship Classes

The prototype demonstration just completed in USS ELMER MONTGOMERY, along with concurrent noise control efforts in USS SOUTH CAROLINA (reference 2 and 9) have demonstrated the feasibility of reducing noise levels in machinery spaces to acceptable hearing damage risk levels. In the past, airborne noise surveys conducted in surface ship machinery spaces documented that hearing hazards exist in all ship classes investigated. Of seven ship types surveyed, eighty percent of the work stations and watch stations exceeded BUMED hearing damage risk limits for all measured conditons. Demonstrated solutions are, therefore, available for long-standing serious problems which cause hearing loss in personnel. It is, therefore, recommended the hearing conservation program address these other classes of active surface ships so that proven noise control approaches can be applied as appropriate to remove hearing hazards in machinery spaces.

The recommended approach to a hearing conservation program necessarily requires that the ships be grouped in classes or sub-classes based on commonality in machinery suite and arrangements and the magnitude and characteristics of noise problems. This step can be accomplished through the collection, review and analysis of machinery arrangements and existing airborne noise survey results. After the ships have grouped into classes and/or sub-classes, it is then considered necessary to conduct an airborne noise trial in at least one ship in each group in order to determine which specific noise sources require treatment. Once the trial results have been analyzed, the noise sources requiring noise reduction can be identified. Appropriate noise reduction treatments can then be selected based on the type of source, degree of noise reduction required, relative cost and other pertinent factors. These treatment designs can then be developed in SHIPALT form and cost estimates refined to complete improvement packages for each of the ship classes and sub-classes which would reduce noise levels to comply with the BUMED hearing damage risk criteria.

Another aspect of a major hearing conservation program is the potential for economies-of-scale. On the MONTGOMERY prototype installation, only previously approved materials were utilized which resulted in some practical problems, some of which were not solved in a completely satisfactory manner. For a major program, long term economies could be expected from the development and/or qualification of improved materials which are acoustically effective and also resistant to moisture, oil vapor and abrasion without costly packaging techniques. It is, therefore, recommended that materials development and qualification be made a part of an overall hearing conservation program.

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APPENDIX A

This appendix contains a summary of the noise measurements taken on the USS MONTGOMERY and the USS DOWNES. It is divided into four sections. The first section describes the microphone locations. These apply to all three sets of data which follow. After the first section there is a summary section for each of the three test sequences, one for the DOWNES and one for each of the two MONTGOMERY tests.

Each of the tests is described first by a test index, which lists the runs which were conducted and matches each run with the run number used to identify it. This is followed by the machinery lineups which show the specific items of machinery which were operating during each run. Finally, a dBA summary shows the A-weighted sound pressure level at the various microphone positions for each run.

TABLE 1A. FIXED MICROPHONE LOCATIONS IN ENGINE ROOM

Mic. Pos.	Description
1.	Middle Level. Above workbench near A/C plant No. 2. 2'-0" aft of Fr. 101, 5'-7" inboard from shell, 5'-6" above deck.
2.	Middle Level. Above log desk between distilling plants. 6'-0" above deck, directly above aft inboard corner of desk.
3.	Lower Level. Starboard of main reduction gear where lube oil purifier workbench would be. 5'-6" forward of aft engine room bulkhead, 4'-5" inboard of starboard stanchion at Fr. 104, 6'-0" above deck.
4.	Upper Level. Aft of EOS. 5'-6" above aft edge of second deck catwalk, 6" to port of HP turbine centerline, approximately 4' aft of EOS window.
5.	Middle Level. Above port side of main reduction gear. 1'-1" inboard of port stanchion of Fr. 104, 4'-6" above deck, 9" aft of stanchion centerline.
6.	Middle Level. Directly above centerline of gear output shaft. 4'-6" above catwalk, directly above handrail.
7.	Lower Level. Port of main reduction gear, between lube oil service pumps. 5'-0" forward of aft engine room bulkhead, directly aft of port stanchion at Fr. 104, 6'-0" above deck.
7A.	Lower Level. Near LO settling tank. 5' above deck.
8.	Middle Level. Forward inboard corner of distilling plant No. 1, near main condenser air ejector. 5'-6" above deck, on diagonal between forward inboard corner of distilling plant No. 1 and starboard stanchion of Fr. 101, 2'-4" from Stanchion centerline.

TABLE 1A *(Cont.)*

Mic. Pos.	Description
9.	Middle Level. Above and between compressor and chill water pump for A/C plant No. 1. 5'-4" above deck, 7'-9" outboard of port stanchion of Fr. 98.
10.	Middle Level. Forward inboard corner of distilling plant No. 2. 5'-10" above deck, 10" outboard of stanchion, 2'-8" forward of stanchion.
11.	Lower Level. Bottom of stairs, forward starboard corner of lower level, near fire pump No. 3 and bilge and brine eductors. 5'-6" above deck, Fr. 97, 5'-0" starboard of forward starboard stanchion, 1'-0" forward of Fr. 97.
12.	Lower Level. Between fire pump No. 3 and main condensate pumps. 4'-9" off of bulkhead 95, 2'-0" inboard of starboard stanchion, 5'-9" above step-down platform.
13.	Lower Level. Main condensate pumps, centerline forward. 4'-6" above deck, 4'-5" aft of bulkhead 95, 1'-0" port of ship centerline.
14.	Upper Level. Above center of main reduction gear. 6" port of ship centerline, 5'-4" above gearcase, 2'-4" forward of Fr. 104.
15.	Lower Level. Above distiller feed pumps. 6'-6" above deck, 3'-10" forward of starboard stanchion at Fr. 104.
17.	Middle Level. Near main condenser air ejector, centerline forward. 4'-0" aft of forward engine room bulkhead, 6" starboard of ship centerline, 4'-0" above deck.
18.	Middle Level. Outboard of distilling plant No. 1, directly above brine overboard eductors, 7'-6" above forward end of outboard brine eductor.

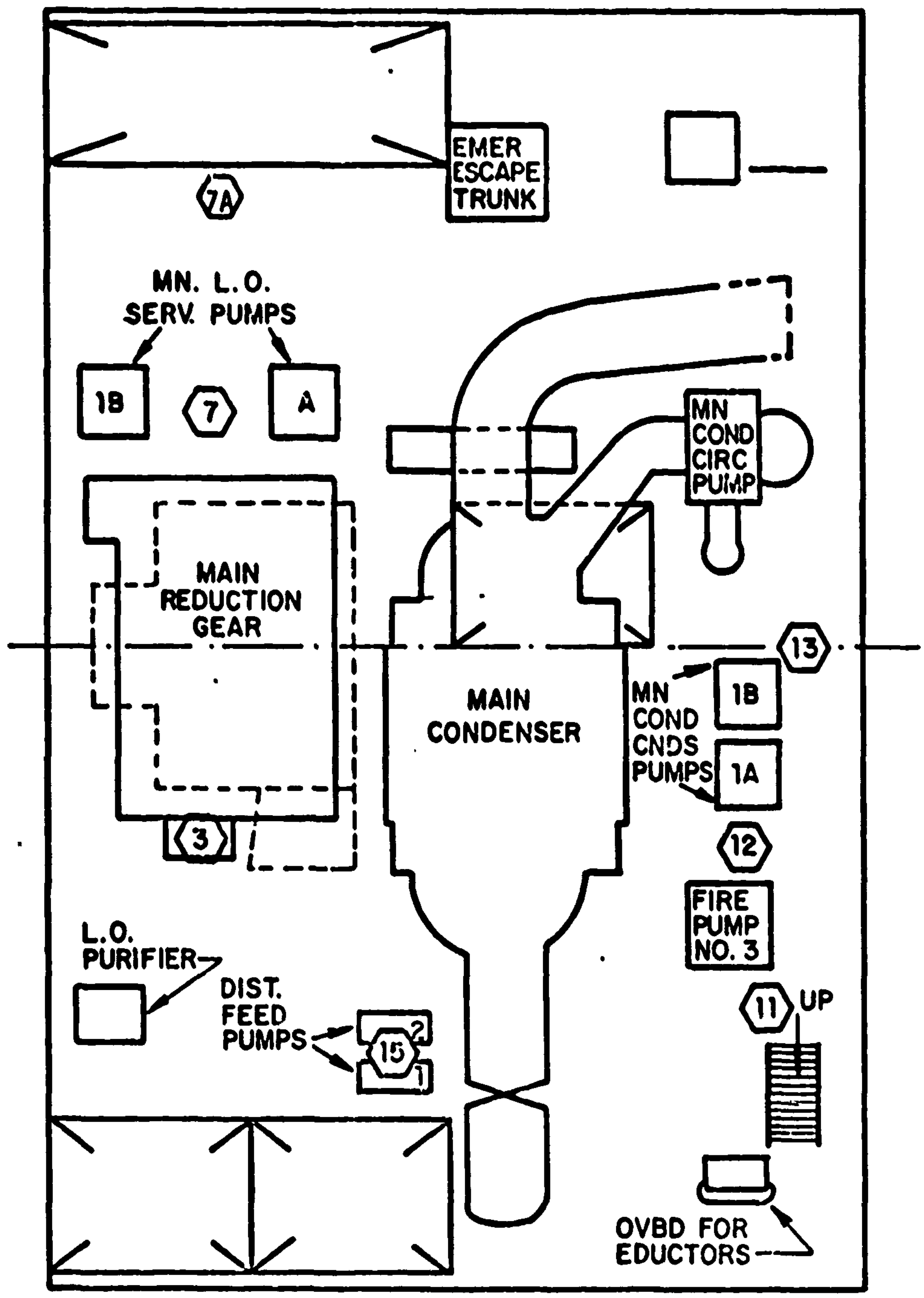

FIG. 1A. ENGINE ROOM - LOWER LEVEL, MACHINERY ARRANGEMENT AND MICROPHONE LOCATIONS.

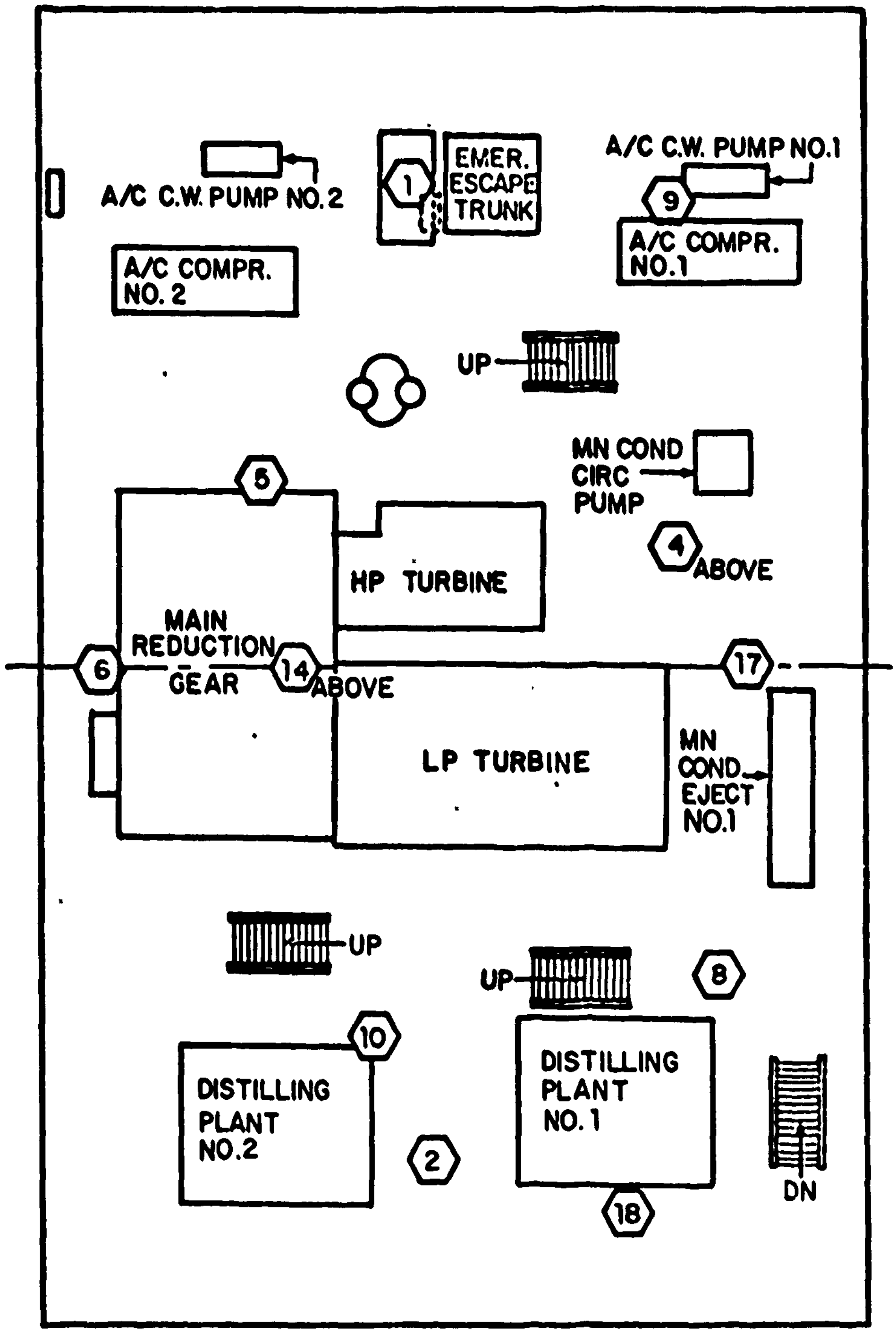

FIG. 1B. ENGINE ROOM - MIDDLE LEVEL, MACHINERY ARRANGEMENT AND MICROPHONE LOCATIONS.

TABLE 1B. FIXED MICROPHONE LOCATIONS IN FIRE ROOM

Mic. Pos.	Description
58.	Lower Level. 2'-0" directly above center of burner cleaning bench.
77.	Lower Level. Between PRAIRIE-MASKER compressor No. 1 and boiler No. 1A. 2'-8" starboard and 3'-1" aft of forward starboard corner of boiler No. 1A, 5'-7" above deck.
79.	Lower Level. Between fuel oil service pump No. 1 and boiler No. 1A. 2'-6" directly outboard of forward port corner of boiler No. 1A, 5'-3" above deck.
81A.	Lower Level. Between boilers, starboard. 2'-10" aft and 3'-2" inboard of aft starboard corner of boiler No. 1A, 6'-2" above deck.
81B.	Lower Level. Between boilers, port. 4'-7" aft and 5'-4" inboard of aft port corner of boiler No. 1A, 5'-11" above deck.
82.	Lower Level. Between PRAIRIE-MASKER compressor No. 2 and boiler No. 1B. 2'-10" starboard and 4'-9" forward of aft starboard corner of boiler No. 1B, 5'-11" above deck.
88.	Upper Level. Forward of main feed pump No. 1C. 2'-9" forward of main feed pump No. 1C, in line with pump axis, 4'-3" above deck.
93.	Lower Level. Near main feed booster pump No. 1B. 1'-9" inboard and 6" forward of forward inboard mount of main feed booster pump No. 1B, 5'-6" above deck.
104.	Lower Level. Between fire pump No. 2 and transfer panel, above wash basin. Directly above inboard edge of basin, 5'-6" above deck.
155.	Upper Level. Above port aft workbench. 2'-6" above vise or aft port workbench.
156.	Upper Level. Port of boiler No. 1A, between stairs. 6'-7" port of boiler No. 1A, 4'-6" forward of control station bulkhead, 6'-1" above deck.

TABLE 1B *(Cont.)*

Mic. Pos.	Description
157.	Upper Level. Centerline between boilers. Center of crosswalk between boilers, 5'-11" above deck.
158.	Upper Level. Aft of main feed pumps Nos. 1A and 1B. 2'-6" aft of aft end of main feed pump No. 1B and 3'-0" port of centerline of pump 1B, 4'-5" above deck.
201.	Second Deck. Centerline between boilers. Center of crosswalk between boilers, 6'-0" above deck.
202.	Second Deck. Foot of forward port stairs to main deck. 13'-2" aft of bulkhead 79, 3'-0" port of boiler No. 1A, 4'-1" above deck.
203.	Main Deck. Center of forward forced draft blower room. Between turbine ends of forced draft blowers 1A1 and 1A2, 5'-6" above deck.
LV	Below large exhaust fan bellmouth.
ATH	Below small exhaust fan bellmouth.
FDB	Forced draft blower room. Between forced draft blowers No. 1A1 and 1A2.

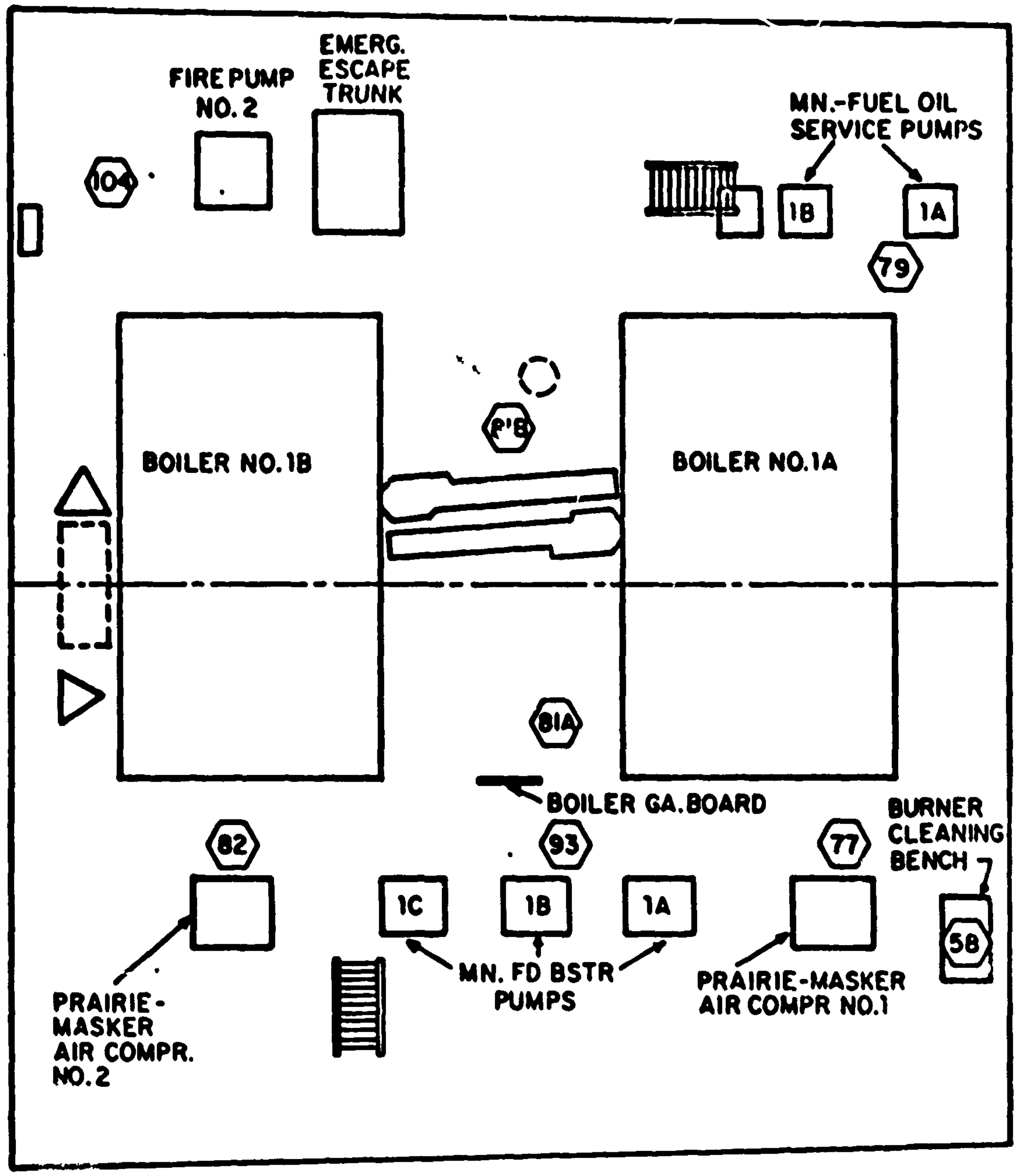

FIG. 1C. FIRE ROOM - LOWER LEVEL, MACHINERY ARRANGEMENT AND MICROPHONE LOCATIONS.

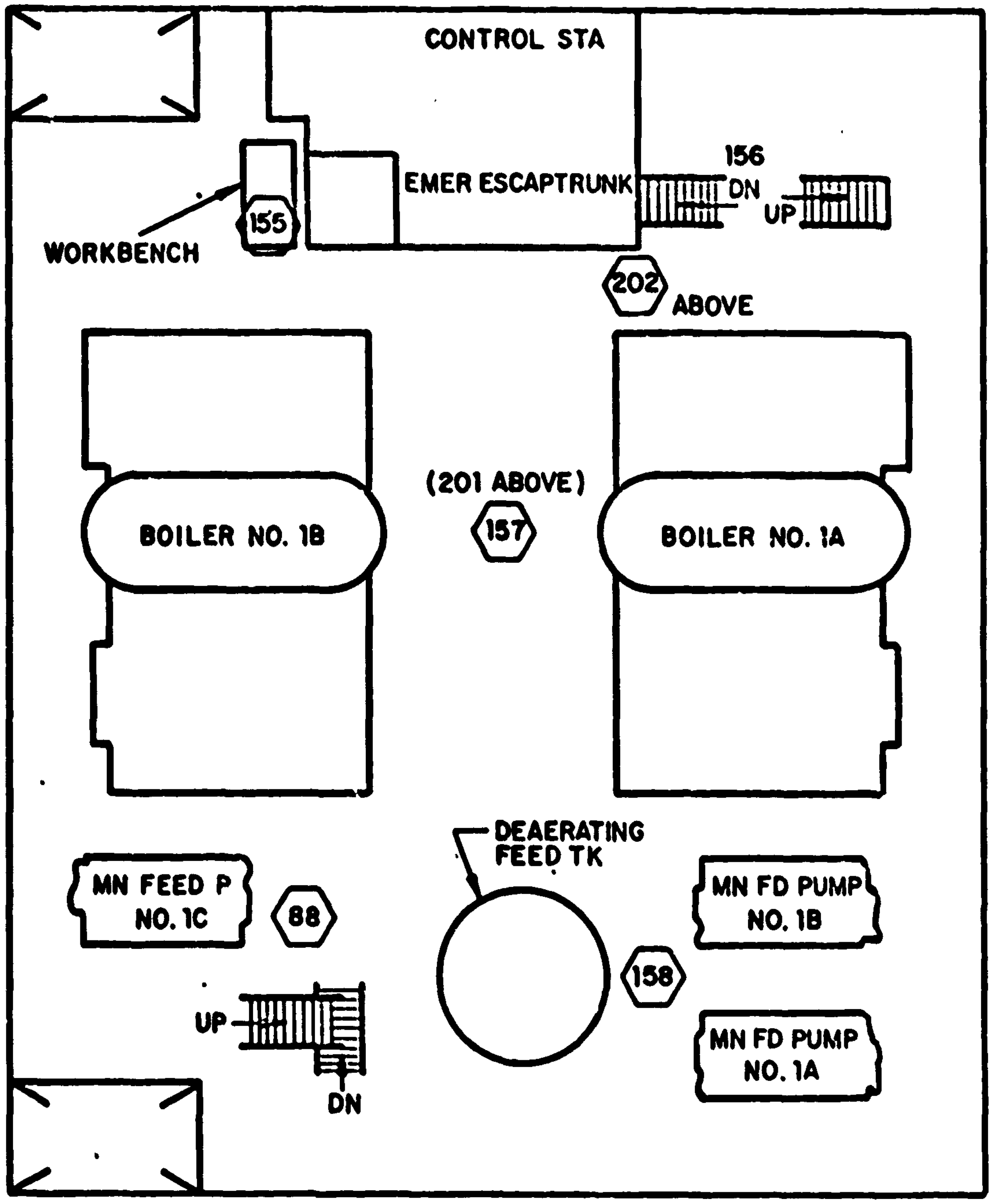

FIG. 1D. FIRE ROOM - MACHINERY ARRANGEMENT AND MICROPHONE LOCATIONS.

TABLE 1C. FIXED MICROPHONE LOCATIONS IN AMR NO. 1

Mic. Pos.	Description
31.	Upper Level. Near workbench and SSTG No. 1A. 6' above deck, 3'-4" inboard from shell, at Fr. 73.
32.	Upper Level. Between SS turbo-generators No. 1A and 1B. 1'-3" forward and 9" inboard of starboard stanchion at Fr. 73, 6'-3" above deck.
33.	Upper Level. Between SS turbo-generators No. 1B and 1C. 2' forward and 4" inboard of port stanchion at Fr. 73, 5'-9" above deck.
34.	Upper Level. Between LP air compressor and HP air compressor. 5' inboard from shell, 3'-8" aft of Fr. 73, 6'-2" above deck.
35.	Upper Level. Forward of FO service tank. 5' above deck, on centerline, 3' forward of FO tank.
36.	Lower Level. Between SS turbo-generators No. 1A and 1B. 1'-8" inboard of starboard stanchion at Fr. 73, 6'-1" above deck.
37.	Lower Level. Between SS turbo-generators No. 1B and 1C. 2' forward and 3' inboard of port stanchion at Fr. 73, 5'-3" above deck.

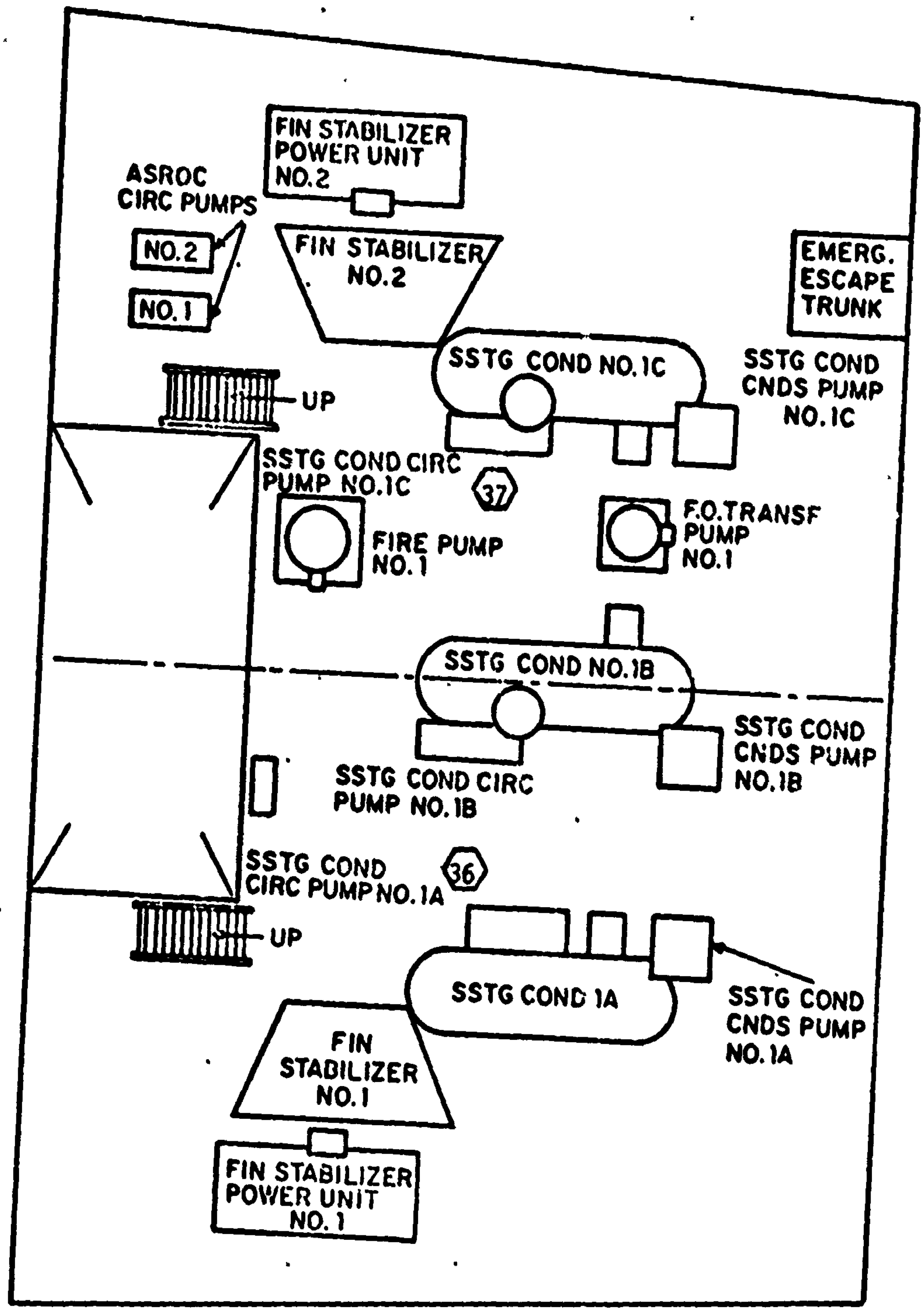

FIG. 1E. AUXILIARY MACHINERY ROOM NO. 1 - LOWER LEVEL MACHINERY ARRANGEMENT.

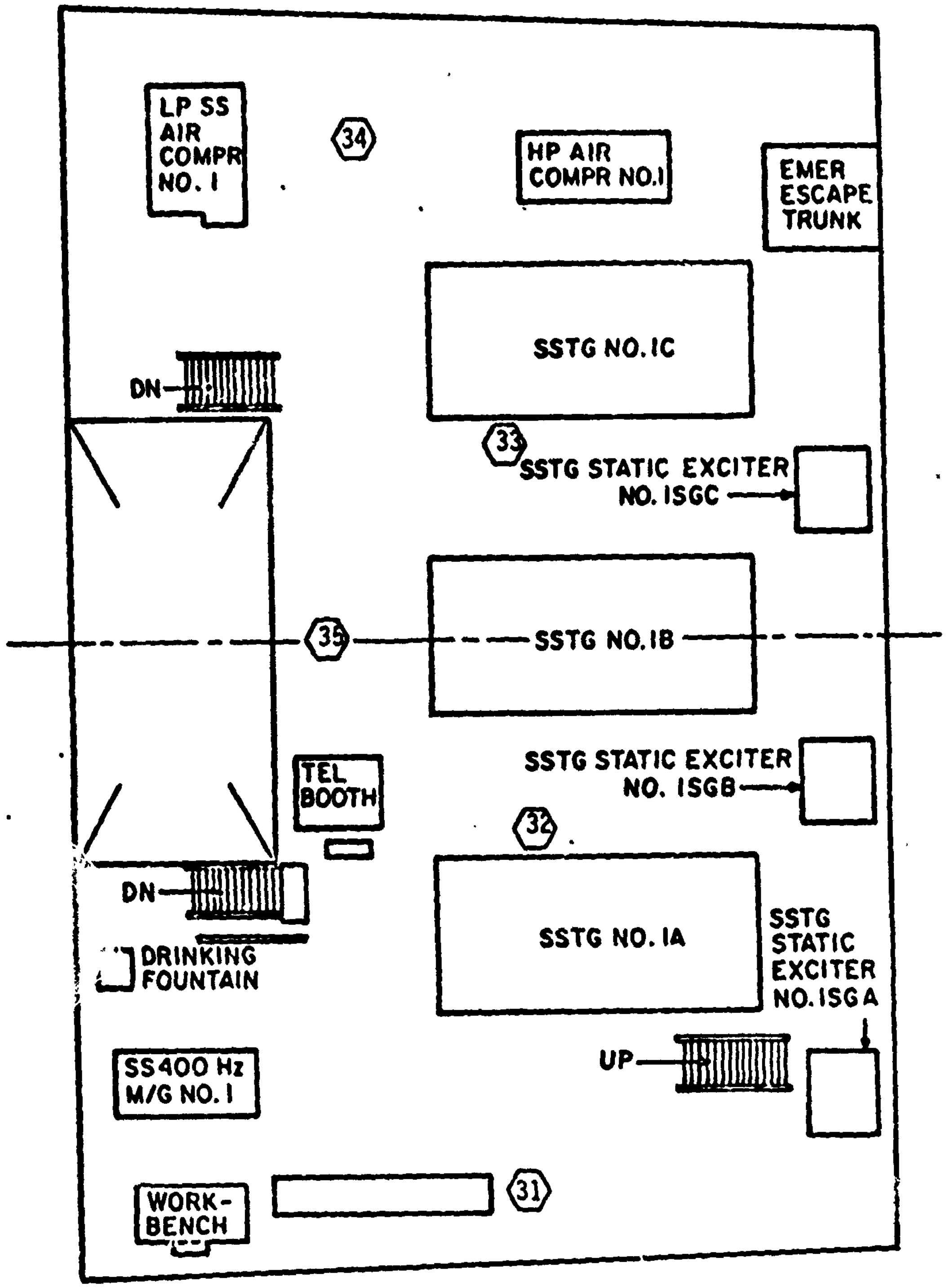

FIG. 1F. AUXILIARY MACHINERY ROOM NO. 1 - UPPER LEVEL MACHINERY ARRANGEMENT.

USS DOWNES AIRBORNE NOISE TRIAL

ENGINE ROOM

Dockside

130	Main Air Ejector and Main Conditioning Pump
131	Main Conditioning Pump
132	Both Distilling Plants
133	Main LO Service Pump (Low Speed)
134	All vents on high
135	Quiet Baseline (SW to A/C Cond.)
135A	Quiet Baseline (SW to A/C Cond. secured)
135B	Quiet Baseline (No. 2 fire pump secured)
136	A/C Plant No. 1
152	Mid Speed Non-propulsion baseline (one cond. pump)
153	High Speed Non-propulsion baseline (two cond. pumps)

Underway

171	80 RPM
172	100 RPM
173	120 RPM
174	140 RPM
175	160 RPM
176	180 RPM
177	200 RPM
171A-177A	Same as 171-177 with stills secured
171B	Same as 171 with stills, A/C plant & vents secured
175B	160 RPM
175C	155 RPM
175D	150 RPM

FIRE ROOM

Dockside

230	Fire Pump No. 2
231	All vents on high
232	Quiet Baseline (MFP LO pump running)
232A	Quiet baseline (MFP LO pumps secured)
233	Vent Supply fans running (FW Drain pumps running)
234	Vent exhaust fans running (FW Drain pumps running)
252	"Non-propulsion" baseline boiler load 21%
1A1	Sound source at FDB 1A1 - Cold Iron

Underway

271	80 RPM
272	100 RPM
273	120 RPM
274	140 RPM
275	160 RPM
276	180 RPM
277	200 RPM
275A	150 RPM
275B	160 RPM
275C	155 RPM
281	119 RPM Baseline for FDB cycling
281A-C	1A1 @ 3000, 4500 & 5600 RPM
281D	1A1 and 1A2 @ 5600 RPM
281E-G	1A2 @ 5600, 4500 & 3000 RPM (1A1 @ 1400 idling)
281H	1A2 @ 5600 (1A1 secured)
282	Gland exhaust secured
283	PM A/C #1A running

AMR NO. 1

Underway

381	Full Machinery Lineup (2 TGs)
382	Baseline for Machinery Cycling
383	Fire Pump #1
384	LP Air Compressor
385	HP Air Compressor
386	Fin Stabilizers
387	ASROC Circulating Pump #1
388	SS 400 Hertz MG set
389	Vent Fans
390	TG #1B - Idling
391	Fin Stabilizers
391A	Fin Stabilizers

DOWNES MACHINERY LINE-UPS FOR ENGINE ROOM DOCKSIDE MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	130	131	132	133	134	135	135A	135B	136	152	153			
Main Reduction Gear														
Propulsion L.P. Turbine														
Propulsion H.P. Turbine														
Main Air Ejector	R													
Main Circulating Pump														
Main Conditioning Pump #1A	R	R									R			
Main Conditioning Pump #1B										R	R			
Main L.O. Service Pump #1A				L										
Main L.O. Service Pump #1B										L	L			
Main L.O. Purifier #1A										R	R			
Distilling Plant #1			R							R	R			
Distilling Plant #2			R							R	R			
Fire Pump #3														
Air Conditioning Comp. #1									R	R	R			
Air Conditioning C.W. Circ. Pump #1									R	R	R			
Air Conditioning Comp. #2														
Air Conditioning C.W. Circ. Pump #2														
Vent Supply Fan #2-103-1					H					H	H			
Vent Supply Fan #2-101-2					H					H	H			
Vent Exhaust Fan #01-101-1					H					H	H			
Vent Exhaust Fan #01-101-4					H					H	H			

R - RUNNING L - LOW SPEED H - HIGH SPEED

DOWNES MACHINERY LINE-UPS FOR ENGINE ROOM UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	171	171A	171B	172	172A	173	173A	174	174A	175	175A	175B	175C	175D
Main Reduction Gear	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Propulsion L.P. Turbine	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Propulsion H.P. Turbine	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Main Air Ejector	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Main Circulating Pump														
Main Conditioning Pump #1A								R	R	R	R	R	R	R
Main Conditioning Pump #1B	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Main L.O. Service Pump #1A														
Main L.O. Service Pump #1B	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Main L.O. Purifier #1A	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Distilling Plant #1	R			R				R		R		R	R	R
Distilling Plant #2	R			R		R		R		R		R	R	R
Fire Pump #3														
Air Conditioning Comp. #1	R	R		R	R	R	R	R	R	R	R	R	R	R
Air Conditioning C.W. Circ. Pump #1	R	R		R	R	R	R	R	R	R	R	R	R	R
Air Conditioning Comp. #2														
Air Conditioning C.W. Circ. Pump #2														
Vent Supply Fan #2-103-1	H	H		H	H	H	H	H	H	H	H	H	H	H
Vent Supply Fan #2-101-2	H	H		H	H	H	H	H	H	H	H	H	H	H
Vent Exhaust Fan #01-101-1	H	H		H	H	H	H	H	H	H	H	H	H	H
Vent Exhaust Fan #01-101-4	H	H		H	H	H	H	H	H	H	H	H	H	H

R - RUNNING L - LOW SPEED H - HIGH SPEED

DOWNES MACHINERY LINE-UPS FOR FIRE ROOM DOCKSIDE MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	230	231	232	232A	233	234	252							
Boiler #1A							R							
Boiler #1B							R							
Forced Draft Blower #1A1														
Forced Draft Blower #1A2							3.2							
Forced Draft Blower #1B1							3.8							
Forced Draft Blower #1B2														
Main Feed Pump #1A							R							
Main Feed Pump #1B							I							
Main Feed Pump #1C														
Main Feed Booster Pump #1A														
Main Feed Booster Pump #1B							R							
Main Feed Booster Pump #1C														
Fuel Oil Service Pump #1A							L							
Fuel Oil Service Pump #1B														
F.W. Drain Pump #1A					R	R	R							
F.W. Drain Pump #1B					R	R	R							
Fire Pump #2	R						R							
Prairie Masker Air Comp. #1A														
Prairie Masker Air Comp. #1B														
Auxiliary Gland Exhaust Fan							R							
Vent Supply Fan #01-84-3		H			H		H							
Vent Supply Fan #1-84-2		H			H		H							
Vent Exhaust Fan #1-85-2		H				H	H							
Vent Exhaust Fan #1-88-1		H				H	H							

R - RUNNING   H - HIGH SPEED   L - LOW SPEED   I - IDLING

BLOWER SPEED IN KRPM

DOWNES MACHINERY LINE-UPS FOR FIRE ROOM UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	271	272	273	274	275	275A	275B	275C	276	277				
Boiler #1A					R				R	R				
Boiler #1B	R	R	R	R	R	R	R	R	R	R				
Forced Draft Blower #1A1					R				R	R				
Forced Draft Blower #1A2					I				R	R				
Forced Draft Blower #1B1	R	R	R	R	R	R	R	R	R	R				
Forced Draft Blower #1B2	I	I	I	R	I	R	R	R	R	R				
Main Feed Pump #1A	I	I	I	R	I	R	R	R	R	R				
Main Feed Pump #1B	R	R	R	R	R	I	I	I	R	R				
Main Feed Pump #1C														
Main Feed Booster Pump #1A				R	R	R	R	R	R	R				
Main Feed Booster Pump #1B	R	R	R	R	R	R	R	R	R	R				
Main Feed Booster Pump #1C														
Fuel Oil Service Pump #1A	L	L	L	L	L	L	L	L	H	H				
Fuel Oil Service Pump #1B														
F.W. Drain Pump #1A	R	R	R	R	R	R	R	R	R	R				
F.W. Drain Pump #1B	R	R	R	R	R	R	R	R	R	R				
Fire Pump #2	R	R	R	R	R	R	R	R	R	R				
Prairie Masker Air Comp. #1A														
Prairie Masker Air Comp. #1B														
Auxiliary Gland Exhaust Fan	R	R	R	R	R	R	R	R	R	R				
Vent Supply Fan #01-34-3	H	H	H	H	H	H	H	H	H	H				
Vent Supply Fan #1-84-2	H	H	H	H	H	H	H	H	H	H				
Vent Exhaust Fan #1-85-2	H	H	H	H	H	H	H	H	H	H				
Vent Exhaust Fan #1-88-1	H	H	H	H	H	H	H	H	H	H				

R - RUNNING H - HIGH SPEED L - LOW SPEED I - IDLING

DOWNES MACHINERY LINE-UPS FOR FIRE ROOM UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	281	281A	281B	281C	281D	281E	281F	281G	281H	282	283			
Boiler #1A														
Boiler #1B	R	R	R	R	R	R	R	R	R	R	R			
Forced Draft Blower #1A1		3.0	4.5	5.6	5.6	I	I	I						
Forced Draft Blower #1A2					5.6	5.6	4.5	3.0	5.6					
Forced Draft Blower #1B1	R	R	R	R	R	R	R	R	R	R	R			
Forced Draft Blower #1B2	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Pump #1A	I	I	I	I	I	I	I	I	R	I	I			
Main Feed Pump #1B	R	R	R	R	R	R	R	R	I	R	R			
Main Feed Pump #1C														
Main Feed Booster Pump #1A	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Booster Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Booster Pump #1C														
Fuel Oil Service Pump #1A	L	L	L	L	L	L	L	L	L	L	L			
Fuel Oil Service Pump #1B														
F.W. Drain Pump #1A	R	R	R	R	R	R	R	R	R	R	R			
F.W. Drain Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Fire Pump #2	R	R	R	R	R	R	R	R	R	R	R			
Prairie Masker Air Comp. #1A											R			
Prairie Masker Air Comp. #1B														
Auxiliary Gland Exhaust Fan	R	R	R	R	R	R	R	R	R		R			
Vent Supply Fan #01-84-3									H					
Vent Supply Fan #1-84-2									H					
Vent Exhaust Fan #1-85-2									H					
Vent Exhaust Fan #1-88-1									H					

R - RUNNING H - HIGH SPEED L - LOW SPEED I - IDLING
BLOWER SPEED IN KRPM

DOWNES MACHINERY LINE-UP FOR AMR NO. 1 UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	381	382	383	384	385	386	387	388	389	390	391	391A		
SS Turbo-generator #1A	R	R	R	R	R	R	R	R	R	R	R	R		
SSTG Circulating Pump #1A	R	R	R	R	R	R	R	R	R	R	R	R		
SSTG Conditioning Pump #1A	R	R	R	R	R	R	R	R	R	R	R	R		
SS Turbo-generator #1B	R	R	R	R	R	R	R	R	R	I	R	R		
SSTG Circulating Pump #1B	R	R	R	R	R	R	R	R	R	R	R	R		
SSTG Conditioning Pump #1B	R	R	R	R	R	R	R	R	R	R	R	R		
SS Turbo-generator #1C														
SSTG Circulating Pump #1C														
SSTG Conditioning Pump #1C														
SSTG Gland Exhaust Fan	R	R	R	R	R	R	R	R	R	R	R	R		
Fire Pump #1	R		R											
L.P. Air Compressor	R			R										
H.P. Air Compressor	R				R									
Fin Stabilizer #1(S)	R	I	I	I	I	R	I	I	I	I	R	R		
Fin Stabilizer #2(P)	R	I	I	I	I	R	I	I	I	I	R	R		
F.O. Transfer Pump														
ASROC Circulating Pump #1	R						R							
ASROC Circulating Pump #2	R													
SS 400 Hz. Motor Generator Set	R							R						
Vent Supply Fan	H								H					
Vent Exhaust Fan	H								H					

R - RUNNING H - HIGH SPEED L - LOW SPEED I - IDLING

DOWNES DBA SUMMARY FOR ENGINE ROOM DOCKSIDE MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	130 Main Air Ejector & Main Cond. Pump	131 Main Cond. Pump	132 Both Distilling Plants	133 Main L.D. Service Pump - Low Speed	134 All Vents on High	135 Quiet Baseline	135A Quiet Baseline	135B Quiet Baseline, Fire Pump #2 Secured	136 A/C Plant #1	152 Mid-Speed Non-Prop. Baseline	153 Hi-Speed Non-Prop. Baseline		
ML	Workbench - A/C #2	1	85	85	85	83	84	84	82	83	86	82	82		
ML	Log Desk by Stills	2	80	74	87	67	79	65	65		68	87	93		
LL	Starboard MRG	3	77	75	87	72	75	69	69			88	88		
ML	Port MRG	5	79	72	76	75	73	69	67		75	79	80		
LL	Port MRG	7A	75	72	75	83	69	63	66		76	83	83		
ML	By Stills -"Times Square"	10A	82	72	85	66	84	62	62		68	88	88		
LL	Between F.P. & Cond P.	12	90	94	90	71	73	70	72		75	92	91		
LL	Forward ℄ Cond Pumps	13	88	88	85	73	74	72	72		79	90	90		
UL	Center of MRG	14	81	71	77	73	74	67	66		74	83	91		
ML	Forward Main Air Ejector	17	89	81	83	72	74	71	69		81	87	87		

DOWNES DBA SUMMARY FOR ENGINE ROOM UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	171 80 RPM	171A 80 RPM with Stills Secured	171B 80 RPM with Stills, A/C Plant & Vents Secured	172 100 RPM	172A 100 RPM with Stills Secured	173 120 RPM	173A 120 RPM with Stills Secured	174 140 RPM	174A 140 RPM with Stills Secured
ML	Workbench - A/C #2	1	84	83	85	87	85	89	86	87	88
ML	Log Desk by Stills	2	89	84	84	90	85	90	88	90	88
LL	Starboard MRG	3	93	93	89	91	90	94	95	95	96
ML	Port MRG	5	88	84	89	92	87	92	89	91	91
LL	Port MRG	7A	90	89	89	91	89	91	92	93	92
ML	By Stills - "Times Square"	10A	89	88	84	90	87	90	88	90	90
LL	Between F.P. & Cond P.	12	95	98	98	95	97	94	95	96	94
LL	Forward ℄ Cond Pumps	13	93	94	94	94	94	95	96	95	95
UL	Center of MRG	14	87	86	88	91	89	89	90	89	90
ML	Forward Main Air Ejector	17	91	91	90	91	91	92	91	92	91

DOWNES DBA SUMMARY FOR ENGINE ROOM UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	175 160 RPM	175A 160 RPM with Stills Secured	175B 160 RPM	175C 155 RPM	175D 150 RPM	176 180 RPM	176A 180 RPM with Stills Secured	177 200 RPM	177A 200 RPM with Stills Secured
ML	Workbench - A/C #2	1	89	89	87	88	88	90	90	91	91
ML	Log Desk by Stills	2	93	92	90	91	91	91	89	92	93
LL	Starboard MRG	3	99	100	101	96	98	96	97	98	98
ML	Port MRG	5	96	91	94	93	94	94	94	96	95
LL	Port MRG	7A	96	96	95	96	96	96	97	97	97
ML	By Stills - "Times Square"	10A	95	93	93	91	91	92	91	93	92
LL	Between F.P. & Cond P.	12	98	98	95	96	94	97	98	98	99
LL	Forward ℄ Cond Pumps	13	99	97	97	96	95	99	100	100	100
UL	Center of MRG	14	93	93	92	94	91	94	94	94	95
ML	Forward Main Air Ejector	17	95	93	92	93	92	95	94	95	95

DOWNES DBA SUMMARY FOR FIRE ROOM DOCKSIDE MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	230 Fire Pump #2	231 Vents on High	232 Quiet Baseline	232A Quiet Baseline	233 Vent Supply Fans	234 Vent Exhaust Fans	252 Non-Prop Baseline	1A1 Sound Source at FDB 1A1
LL	Burner Clean Bench	58							87	
LL	Between Boilers Starboard	81A.	74	80	69	69	78	76	87	
LL	Between PM #1B & Blr. #1B	82							91	
UL	Forward Main FD #1C	88	76	80	74	74	75	80	92	
LL	Fire Pump #2	104	91	80	73	73	80	78	46/9[illegible]	
UL	Workbench	155	82	85	66	67	85	72	85	
UL	Between Ladders Port Fwd.	156	69	77	62	62	77	67	85	
UL	Boilers ℄	157	72	86	80	80	83	85	91	
UL	Main FD #1A & 1B	158	74	79	79	78	75	78	90	
2D	Boilers ℄	201	72	88	69	69	81	88	96	
2D	Foot of Fwd. Port Stairs	202				70	82	79		
	Below Small Exhaust Fan Bell.	ATH				70	83	103		73
	Below Large Exhaust Fan Bell.	LV				65/74	80	106		77

DOWNES DBA SUMMARY FOR FIRE ROOM UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	271 80 RPM	272 100 RPM	273 120 RPM	274 140 RPM	275 160 RPM	275A 150 RPM	275B 160 PPM	275C 155 RPM	276 180 RPM	277 200 RPM	283 PM A/C #1A Running		
LL	Burner Clean Bench	58											87		
LL	Between PM #1 & Boiler #1A	77											90		
LL	Between Boilers Sharboard	81A	87	86	90	93	90	89	92	92	91	94	87		
LL	Between PM #1B & Blr #1B	82	82	83	88	86	90	98	100	100	87	94			
UL	Forward Main FD #1C	88	91	92	99	95	98	92	95	93	94	96	92		
LL	Fire Pump #2	104	91	93	95	97	97	94	96	97	97	99	89		
UL	Workbench	155	88	88	91	97	91	93	98	99	94	96	88		
UL	Between Ladders Port Fwd.	156	82	82	83	83	88	87	86	85	90		79		
UL	Boilers ℄	157	91	92	97	93	96	95	98	95	96	99	93		
UL	Main FD #1A & #1B	158	90	91	91	91	95	90	91	90	96	97	90		
2D	Boilers ℄	201	92	92	97	96	97	94	98	96	97	100	90		

DOWNES DBA SUMMARY FOR FIRE ROOM UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	281 119 RPM Baseline for FDB Cycling	281A FDB 1A1 @ 3000 RPM	281B FDB 1A1 @ 4500 RPM	281C FDB 1A1 @ 5600 RPM	281D FDB 1A1 & 1A2 @ 5600 RPM	281E FDB 1A2 @ 5600 RPM	281F FDB 1A2 @ 4500 RPM	281G FDB 1A2 @ 300 PRM	281H Same as 281E with FDB 1A1 Secured	282 Gland Exhaust Secrd			
20	Boiler G	201	93	93	95	97	99	98	96	91		94			
	Between FDB 1A1 and 1A2	FDB	78	87	98	101	100	103	95	88	97				
	Below large exhaust fan Bellmouth	LV	102	106	104	107	108	108	107	107		103			
	Below small exhaust fan Bellmouth	ATH	105	104	106	105	108	109	104						

DOWNES DBA SUMMARY FOR AMR NO. 1 UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	381 Full Machinery Lineup (2 SSTG'S)	382 Baseline for Machinery Cyc.ing	383 Fire Pump #1	384 L.P. Air Compressor	385 H.P. Air Compressor	386 Fin Stabilizers	387 ASROC Circ Pump #1	388 SS 400 Hz M.G. Set	389 Vent Fans	SSTG #1B - Idling			
UL	Starboard Workbench	31	87	83	83	83	83	82	83	86	83	83			
UL	Inboard TG #1A Stbd	32	91	90	92	89	89	89	90	90	90	91			
UL	Inboard TG #1C Stbd	33	87	87	87	87	83	88	87	87	87	86			
UL	Between Air Comp Port	34	88	85	84	94	85	85	82	81	81	85			
UL	℄ of Aft BHD	35	87	87	85	86	86	85	90	85	86	86			
LL	Starboard Inbd TG #1A	36	91	91	89	89	90	90	90	90	89	90			
LL	Port Inbd TG #1C	37	92	91	90	91	89	89	89	89	88	89			

MONTGOMERY PRE-RAV

TEST INDEX

ENGINE ROOM

Dockside

401	Baseline
402	LO Purifier #1A
403	Main Air Ejector #1B
404	Main Conditioning Circulating Pump - Low Speed
404A	Main Conditioning Circulating Pump - High Speed
405	Fire Pump #3
406	Ventilation Fans
407	Main Conditioning Pump #1B
409	Main LO Service Pump #1B - Low Speed
409A	Main LO Service Pump #1B - High Speed
412	Distilling Plant #1
424	Air Conditioning CW Circulating Pump #1
425	Air Conditioning Pump and Compressor #1
426	Air Conditioning Pump and Compressor #2
429	Non-Propulsion Baseline - Conditioning Pumps, stills and Main Circulating Pump
430	Distilling Plants #1 and #2

Underway

1001	Baseline 160 RPM
1002	Same as 1001 with Brine Eductors secured
1003	Same as 1001 with Distilling Plants secured
1004	Same as 1003 with Fire Pump secured
1005	Same as 1004 with Main Conditioning Pump #1B secured
1006	Same as 1005 with Main Circulating Pump - Fast
1007	Same as 1005 with Main LO Service Pump #1A secured
1009	Same as 1005 with A/C Plant #2 secured
1010	160 RPM
1011	Baseline 180 RPM
1021	Baseline 200 RPM

FIRE ROOM

Dockside

3001A	Boiler #1A, Blowers #1A1 and 1B1 @ 3000 RPM
3001B	Same as 3001A with FDB #1B1 @ 4500 RPM

MONTGOMERY PRE-RAV

3001C	Same as 3001A with FDB #1B1 @ 5600 RPM
3002A	Same as 3001A with FDB #1B2 @ 3000 RPM
3002B	Same as 3002A without FDB #1B1 and with FDB #1B2 @ 4500
3002C	Same as 3002B with FDB #1B2 @ 5600 RPM
3003	Same as 3008 with Main Feed Booster #1C
3004	Same as 3008 with Fire Pump #2
3005	Same as 3008 with FO Service Pump #1B instead of #1A
3007	Same as 3005 with P/M A/C #1B
3008	Quiet Baseline, Boiler #1A, Blower #1A1
V-1	Ventilation Fans - High Speed

Underway

2001	Baseline 160 RPM
2002	FO Blower 1A1 into Cold Boiler/A @ 3000 RPM
2003	Same as 2002 with FDB 1A1 @ 4500 RPM
2004	Same as 2002 with FDB 1A1 @ 3000 RPM and FDB 1A2 @ 3000 RPM
2005	Same as 2001 with Main Feed Pump #1A instead of #1C
2007	P/M A/Cs #1A and 1B Venting to Space
2007A	P/M A/Cs #1A and 1B Venting to Belts
2010	Baseline - 2 Boilers, Fire Pump
2011	Baseline - 1 Boiler, Fire Pump, and P/M #2
2020	Baseline - 180 RPM
2030	Baseline - 200 RPM

MONTGOMERY PRE-RAV MACHINERY LINEUPS FOR ENGINE ROOM DOCKSIDE TESTS

MACHINERY ITEM	RUN NUMBER															
	401	402	403	404	404A	405	406	407	408	409A	412	424	425	426	429	430
Main Reduction Gear																
Propulsion L.P. Turbine																
Propulsion H.P. Turbine																
Main Air Ejector			R												R	
Main Circulating Pump				L	H										H	
Main Conditioning Pump #1A															R	
Main Conditioning Pump #1B								R							R	
Main L.O. Service Pump #1A																
Main L.O. Service Pump #1B									H	L					L	
Main L.O. Purifier #1A		R													R	
Distilling Plant #1											R				R	R
Distilling Plant #2															R	R
Fire Pump #3						R									R	
Air Conditioning Comp. #1													R		R	
Air Conditioning CW Pump #1												R	R		R	
Air Cond. Compressor #2														R	R	
Air Cond. CW. Pump #2														R	R	
Ventilation Fans							R								R	

R - RUNNING L - LOW SPEED H - HIGH SPEED

MONTGOMERY PRE-RAV MACHINERY LINE-UPS FOR ENGINE ROOM UNDERWAY TESTS

MACHINERY ITEM	RUN NUMBER													
	1001	1002	1003	1004	1005	1006	1007	1009	1010	1011	1021			
Main Reduction Gear	R	R	R	R	R	R	R	R	R	R	R			
Propulsion L.P. Turbine	R	R	R	R	R	R	R	R	R	R	R			
Propulsion H.P. Turbine	R	R	R	R	R	R	R	R	R	R	R			
Main Air Ejector	R	R	R	R	R	R	R	R	R	R	R			
Main Circulating Pump						H								
Main Conditioning Pump #1A										R	R			
Main Conditioning Pump #1B	R	R	R	R						R	R			
Main L.O. Service Pump #1A	S	S	S	S	S	S		S	S	S	S			
Main L.O. Service Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Main L.O. Purifier #1A	R	R								R	R			
Distilling Plant #1	R									R	R			
Dist. Brine Overboarc Educt. #1	R									R	R			
Distilling Plant #2	R	R								R	R			
Dist. Brine Overboard Educt. #2	R									R	R			
Fire Pump #3	R	R	R							R	R			
Air Conditioning Compressor #1	R	R	R	R	R	R	R	R	R	R	R			
Air Conditioning C.W. Pump #1	R	R	R	R	R	R	R	R	R	R	R			
Air Conditioning Compressor #2	R	R	R	R	R	R	R		R	R				
Air Conditioning C.W. Pump #2	R	R	R	R	R	R	R		R	R				
Ventilation Fans	R	R	R	R	R	R	R	R	R	R	R			

R - RUNNING H - HIGH SPEED L - LOW SPEED S - STAND BY

MONTGOMERY PRE-RAV MACHINERY LINE-UPS FOR FIRE ROOM DOCKSIDE MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	3001A	3001B	3001C	3002A	3002B	3002C	3003	3004	3005	3007	3008	V-1		
Boiler #1A	R	R	R	R	R	R	R	R	R	R	R			
Boiler #1B														
Forced Draft Blower #1A1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0			
Forced Draft Blower #1A2														
Forced Draft Blower #1B1	3.0	4.5	5.6	3.0										
Forced Draft Blower #1B2				3.0	4.5	5.6								
Main Feed Pump #1A														
Main Feed Pump #1B														
Main Feed Pump #1C	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Booster Pump #1A														
Main Feed Booster Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Booster Pump #1C							R							
Fuel Oil Service Pump #1A	L	L	L	L	L	L	L	L			L			
Fuel Oil Service Pump #1B									L	L				
F.W. Drain Pump #1A	R	R	R	R	R	R	R	R	R	R	R			
Fire Pump #2								R						
Prairie-Masker Air Comp. #1A														
Prairie-Masker Air Comp. #1B										R				
Auxiliary Gland Exhaust Fan														
Ventilation Fans												R		

H - HIGH SPEED L - LOW SPEED I - IDLE

BLOWER SPEEDS IN KRPM

MONTGOMERY PRE-RAV MACHINERY LINE-UPS FOR FIRE ROOM UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	2001	2002	2003	2004	2005	2007	2007A	2010	2011	2020	2030			
Boiler #1A								R		R	R			
Boiler #1B	R	R	R	R	R	R	R	R	R	R	R	R		
Forced Draft Blower #1A1		3.0	4.5	3.0										
Forced Draft Blower #1A2				3.0				3.0		R	R			
Forced Draft Blower #1B1	R	R	R	R	R	R	R	R	R	R	R			
Forced Draft Blower #1B2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	R	R	R			
Main Feed Pump #1A	I/	I/	I/	I/	R	R	R	I/	I/	I/	I/			
Main Feed Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Pump #1C	R	R	R	R	I/	I/	I/	R	R	R	R			
Main Feed Booster Pump #1A	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Booster Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Main Feed Booster Pump #1C	I/	I/	I/	I/	I/	I/	I/	I/	I/	I/	I/			
Fuel Oil Service Pump #1A	R	R	R	R	R	R	R	R	R	R	R			
Fuel Oil Service Pump #1B	I/	I/	I/	I/	I/	I/	I/	I/	I/	I/	I/			
F.W. Drain Pump #1A	R	R	R	R	R	R	R	R	R	R	R			
Fire Pump #2								R	R	R	R			
Prairie-Masker Air Comp. #1A						R	R							
Prairie-Masker Air Comp. #1B						R	R		R					
Auxiliary Gland Exhaust Fan	R	R	R	R	R	R	R	R	R	R	R			
Ventilation Fans														

R - RUNNING H - HIGH SPEED L - LOW SPEED I - IDLE

BLOWER SPEEDS IN KRPM

MONTGOMERY PRE-RAV DBA SUMMARY FOR ENGINE ROOM DOCKSIDE TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	401 BASELINE - MAIN STEAM	402 LO PURIFIER	403 MAIN AIR EJECTOR #1B	404 MAIN COND. CIRC. PUMP - SLOW.	404A MAIN COND CIRC. PUMP - FAST	405 FIRE PUMP #3	406 VENT FANS	407 MAIN COND PUMP #1B	409 MAIN LO SERVICE PUMP #1B - FAST	409A MAIN LO SERVICE PUMP #1B - SLOW	412 DIST. PLANT #1	424 A/C C.W. PUMP #1	425 A/C PUMP & COMP #1	426 A/C PUMP & COMP #2	429 DIST. PLANTS 1 & 2, CIRC PUMP - FAST	430 DIST. PLANTS 1 & 2
ML	Workbench-A/C Plant 2	1	67					85	80		74	70	81	69	78	85	84	73
ML	Stbd Btwn Dist Plants	2	69	70				77	70				83				83	87
LL	Stbd LO Purifier Area	3	69	81				81	71				83				89	87
UL	Aft of EOS	4	80										80	81	82	82	86	81
ML	Port MR Gear	5	75					76	80		78	76	81	76	77	81	85	78
ML	Above ℄ Gear Output	6	76	78							80.	79	80	79	80	81	86	81
LL	Port Btwn LO Ser Pumps	7	92															
ML	Stbd Cnr Dist Plant 1	8	72		78	75	75	85	75		74	74	85				91	88
ML	Port A/C Plant 1	9	66										69	74	88	87	83	72
ML	Stbd Dist Plant 2	10	71					77	75		75	73	80				90	89
LL	Stbd, Educs. & Fire P	11	70		75	71	74	88	71	73			88				93	91
LL	Between Fire P & Con P	12	71			73	78	89	71	73	75	75	83				92	86
LL	Forward ℄ Cond Pumps	13	67			77	81	82	72	73			82				89	83
UL	℄ above Ctr MR Gear	14											77	75	77	78	84	79
LL	Stbd above Dist Feed P	15	69	79				85					89					83
ML	℄ Fwd Main Air Eject.	17	80		83								77	71	79	79	89	80
ML	Stbd Dist Plnt & Brine Eductors	18	67		70			80					88				91	90

MONTGOMERY PRE-RAV. DBA SUMMARY FOR ENGINE ROOM UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	1001 Baseline 160 RPM	1002 Same as 1001 without Eductors	1003 Same as 1001 without Stills	1004 Same as 1001 without F.P.	1005 Same as 1004 without Mn Cond Pump IB	1006 Same as 1005 with Mn Circ Pump - Fast	1007 Same as 1005 without Mn L.O. Sen Pump 1A	1009 Same as 1005 without A/C Plant #2	1010 Same as 1005 with Atchd L.O. Pump Sec	1011 Baseline 180 RPM	1021 Baseline 200 RPM		
ML	Workbench - A/C Plant #2	1	92												
ML	Stbd. Between Dist. Plants	2	92	94											
LL	Stbd. L.O. Purifier Area	3	101	101	100		99		102	101	97	100	102		
UL	Aft of EOS	4	94	94	94		94	92	93	95	93	94	96		
ML	Port MR Gear	5	97	98											
ML	Above ℄ Gear Output	6													
LL	Port Between L.O. Serv. Pumps	7													
ML	Stbd. Corner Dist Plant #1	8	94	94											
ML	Port A/C Plant #1	9													
ML	Stbd. Dist. Plant #2	10	94	99											
LL	Stbd. Eductors & Fire Pump	11	97	94	96	94	94	95	94	95	95	96	98		
LL	Between F.P. and Cond. Pump	12	98		98	97	96	98	98	97	98	98	99		
LL	Forward ℄ Cond. Pumps	13	97		97	96	96	97	97	97	97	99	99		
UL	℄ Above Ctr. of MR Gear	14	94		95	94	95	95	94	96	93	94	97		
LL	Stbd. Above Dist. Feed Pumps	15	91	83											
ML	℄ Forward Main Air Ejector	17	93												
ML	Stbd. Dist. Plant and Brine Educts.	18	93	91											

MONTGOMERY PRE-RAV DBA SUMMARY FOR FIRE ROOM DOCKSIDE MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	3001A Boiler 1A, Blowers 1A1, 1B1	3001B Boiler 1A, Blowers 1A1, 1B1	3001C Boiler 1A, Blowers 1A1, 1B1	3002A Boiler 1A, Blowers 1A1, 1B1, 1B2	3002B Boiler 1A, Blowers 1A1, 1B2	3002C Boiler 1A, Blowers 1A1, 1B2	3003 Boiler 1A, Blower 1A1, Mn Fd Boost 1C	3004 Fire Pump 2	3005 F.O. Svc Pump 1B	3007 P/M A/C #1B	3008 Quiet Baseline	V-1 Ventilation Fans
LL	Burner Cleaning Bench	58										83		
LL	Stbd. Fwd. P/M A/C #1	77											89	
LL	Port Fwd. F.O. Serv. Pumps #1, #2	79									88		93	88
LL	Firing Alley	81A	89	91	91	91	90	91	88	99	88	91	89	85
LL	Stbd. Aft P/M A/C #2	82										91	87	83
UL	Stbd. Near Mn. Fd. #1C	88							91				91	87
LL	Stbd. Mn. Fd. Boosters	93											110	82
LL	Port Aft Above Wash Basin	104							88			84	83	79
LL	Port Aft Above Work Bench	155								84			83	76
UL	Port Between Stairs	156	89	90	90	90	90	91				94	86	83
UL	℄ Between Boilers	157	98	99	94	99	98	100	96	96	96		97	91
UL	Stbd. Aft of Mn. Fd. Pumps	158							93				91	81
2D	Ctr. Between Boilers	201	100	102	101	100	99	99					96	97
2D	Foot of Stairs to FDB Room	202	90	91	91	91	93	94					83	79
MD	℄ Between FD Blowers 1A1 & 1A2	203	95	93	96	93	96	93					91	

MONTGOMERY PRE-RAV DBA SUMMARY FOR FIREROOM UNDERWAY MACHINERY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	2001 Baseline 160 RPM	2002 FDB 1A1 into Cold Boiler 1A @ 3000 RPM	2003 Same as 2002 @ 4500 RPM	2004 Same as 2002 @ 5500 RPM with FDB #1A2 @ 3000 RPM	2005 Same as 2001 with Mn Fd Pump 1A without Mn Fd Pump 1C	2007 P/M A/Cs #1A & 1B Venting to Space	2007A P/M A/Cs #1A & 1B Venting to Bilge	2010 Baseline - 2 Boilers, Fire Pump	2011 Baseline - 1 Boiler, F.P., P/M #2	2020 Baseline 100 RPM	2033 Baseline 200 RPM		
LL	Burner Cleaning Bench	58													
LL	Stbd. Fwd. P/M A/C #1	77	89	90	94	92		107	97	88	93	91	93		
LL	Port Fwd. F.O. Serv. Pumps #1 & 2	79	88	90	91	92	88	100	94	90	88	88	96		
LL	Firing Alley	81A	94	93	95	95	95	107	101	90	95	93	94		
LL	Stbd. Aft P/M A/C #2	82	93	92	93	93		104	99	88	94	90	92		
LL	Stbd. Near Mn. Fd. #1C	88	103	104	103	101	102	109	105	91	101	95	100		
LL	Stbd. Mn. Fd. Boosters	93	95	93	96	93	93	106	100	90	95	91	94		
LL	Stbd. Aft Above Washbasin	104	95	94	95	95	94	102	97	94	95	92	94		
LL	Stbd. Aft Above Workbench	155	100	99	100	101	100	104	102	92	100	93	98		
LL	Port Between Stairs	156	88	89	93	93	88	102	95	94	89	92	97		
UL	℄ Between Boilers	157	101	100		102	102	117	110	99	102	100	102		
UL	Stbd. Aft of Mn. Fd. Pumps	158	95	94	98	95	95	106	100	90	95	93	96		
2D	Ctr. Between Boilers	201	101	102	103	102	102	125	119	96	106	100	103		
2D	Foot of Stairs to FDB Room	202	95	96	95	98	94	107	100	97	94	94	102		
ND	℄ Between FD Blowers 1A1 & 1A2	203	85	95	97	97	84	90	85	96	82	97	96		

MONTGOMERY POST-RAV

TEST INDEX

ENGINE ROOM

Dockside

100	Quiet Baseline
101	Vent System Baseline (No. 01-101-4 Low Speed)
101A	Vent System Baseline (No. 01-101-1 Low Speed)
102	Auxiliaries and Vents
102A	Auxiliaries and Vents with Fire Pump Secured
103	Low Speed Baseline - Includes Main Circulating Pump
119	Fire Pump No. 3
152	Mid-Speed Non-propulsion Baseline (one conditioning pump one still and Main Circulating Pump)
152A	Same as 152 with Main Circulating Pump secured
152B	Same as 152A with Fire Pump No. 3 secured
152C	Same as 152B with both stills running
152D	Same as 152C with Fire Pump #3 running
152E	Same as 152D with stills secured

Underway

175	160 RPM
176	180 RPM
177	200 RPM
178	220 RPM
177A	Same as 177 with stills, Air Conditioning Plant and Fire Pump secured
181	160 RPM Baseline
182	Same as 181 with one still secured
183	Same as 181 with both stills secured
184	Same as 183 with Fire Pump and Air Conditioning Plant Secured
186	Same as 183 with Fire Pump secured
189	Same as 183 with Air Conditioning Plant secured

FIRE ROOM

Dockside

200A	Quiet Baseline
201	Vent System Baseline
202	Supply Fan No. 1-84-2, Exhaust Fan No. 1-85-2
203	Supply Fan No. 1-84-3, Exhaust Fan No. 1-88-2

MONTGOMERY POST-RAV

204	Non-propulsion Baseline
205	Fire Pump No. 2
206	Auxiliary Gland Exhaust Fan
250	One Boiler Baseline (no vents)
251	Same as 250 with FDB 1B1 at 3000 RPM
252	Same as 250 with FDB 1B1 at 4500 RPM
253	Same as 250 with FDB 1B1 and 1B2 at 3000 RPM
255	Same as 250 with FDB 1B2 at 4500 RPM
256	Same as 250 with FDB 1B2 at 5000 RPM

Underway

275	160 RPM
276	180 RPM
277	200 RPM
278	220 RPM
275A	160 RPM
285	160 RPM with Prairie-Masker 1A
285A	Same as 285 with Main Feed Booster Pump No. 1C secured
285B	Same as 285A with Prairie Masker and FDBS secured
287	160 RPM with Prairie-Masker No. 1B
288	160 RPM

AMR NO. 1

Dockside

301	Ventilation Fans on High Speed
313	Quiet Baseline (Turbo-generator Circulating Pump #1B running)
318	Air Compressors, ASROC Circulating Pump #2, 400 Hz. Motor Generator Set and Vent Exhaust
318A	Same as 318 with Vent Supply fan running and 400 Hz. set secured
319	Same as 318 with Vent Supply Fan and Fin Stabilizers running
386	SSTG Load: #1A-240, #1C-240
387	SSTG Load: #1A-470, #1C-Idling
388	SSTG Load: #1A-Idling, #1C-530
389B	SSTG Load: #1A-580, #1C-Secured

Underway

375	160 RPM - SSTG Load: #1A-310, #1C-310
375A	160 RPM - SSTG Load: #1A-330, #1C-330
376	180 RPM - SSTG Load: #1A-300, #1C-300
377	200 RPM - SSTG Load: #1A-290, #1C-290
378	220 RPM - SSTG Load: #1A-310, #1C-310
381	Fin Stabilizers
382	Baseline for Fin Stabilizers

MONTGOMERY POST-RAV MACHINERY LINEUPS FOR ENGINE ROOM DOCKSIDE MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	100	101	101A	102	102A	103	119	152	152A	152B	152C	152D	152E	
Main Reduction Gear														
Propulsion L.P. Turbine														
Propulsion H.P. Turbine														
Main Air Ejector								R	R	R	R	R	R	
Main Circulating Pump						H		H						
Main Conditioning Pump #1A														
Main Conditioning Pump #1B								R	R	R	R	R	R	
Main L.O. Service Pump #1A				L	L	L		H	H	H	H	H	H	
Main L.O. Service Pump #1B														
Main L.O. Purifier #1A				R	R	R		R	R	R	R	R	R	
Distilling Plant #1											R	R		
Distilling Plant #2								R	R	R	R	R		
Fire Pump #3				R		R	R	R	R			R	R	
Air Conditioning Comp. #1				R	R	R		R	R	R	R	R	R	
Air Conditioning C.W. Circ. Pump #1				R	R	R		R	R	R	R	R	R	
Air Conditioning Compressor No. 2														
Air Conditioning C.W. Circ. Pump #2														
Vent Supply Fan No. 2-103-1		H	H	H	H	H		H	H	H	H	H	H	
Vent Supply Fan No. 2-101-2		H	H	H	H	H		H	H	H	H	H	H	
Vent Exhaust Fan No. 01-101-1		H	L	L	L	L		H	H	H	H	H	H	
Vent Exhaust Fan No. 01-101-4		L	H	H	H	H		H	H	H	H	H	H	

R - RUNNING L - LOW SPEED H - HIGH SPEED

MONTGOMERY POST-RAV MACHINERY LINE-UPS FOR ENGINE ROOM UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	175	176	177	177A	178	181	182	183	184	186	189			
Main Reduction Gear	R	R	R	R	R	R	R	R	R	R	R			
Propulsion L.P. Turbine	R	R	R	R	R	R	R	R	R	R	R			
Propulsion H.P. Turbine	R	R	R	R	R	R	R	R	R	R	R			
Main Air Ejector	R	R	R	R	R	R	R	R	R	R	R			
Main Circulating Pump														
Main Conditioning Pump #1A		R	R	R	R									
Main Conditioning Pump #1B	R	R	R	R	R	R	R	R	R	R	R			
Main L.O. Service Pump #1A														
Main L.O. Service Pump #1B	L	L	L	L	L	L	L	L	L	L	L			
Main L.O. Purifier #1A	R	R	R	R	R	R	R	R	R	R	R			
Distilling Plant #1	R	R	R		R	R	R							
Distilling Plant #2	R	R	R		R	R								
Fire Pump #3	R	R	R		R	R	R	R			R			
Air Conditioning Comp. #1	R	R	R		R	R	R	R		R				
Air Conditioning C.W. Circ. Pump #1	R	R	R		R	R	R	R		R				
Vent Supply Fan No. 2-103-1	H	H	H	H	H	H	H	H	H	H	H			
Vent Supply Fan No. 2-101-2	H	H	H	H	H	H	H	H	H	H	H			
Vent Exhaust Fan No. 01-101-1	H	H	H	H	H	H	H	H	H	H	H			
Vent Exhaust Fan No. 01-101-4	H	H	H	H	H	H	H	H	H	H	H			

R - RUNNING L - LOW SPEED H - HIGH SPEED

MONTGOMERY POST-RAV MACHINERY LINE-UPS FOR FIRE ROOM DOCKSIDE MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER														
	200A	201	202	203	204	205	206	250	251	252	253	254	255	256
Boiler #1A								R	R	R	R	R	R	R
Boiler #1B														
Forced Draft Blower #1A1														
Forced Draft Blower #1A2								2.0	2.0	2.0	2.0	2.0	2.0	2.0
Forced Draft Blower #1B1									3.0	4.5	5.0	3.0		
Forced Draft Blower #1B2												3.0	4.5	5.0
Main Feed Pump #1A														
Main Feed Pump #1B								R	R	R	R	R	R	R
Main Feed Pump #1C								I	I	I	I	I	I	I
Main Feed Booster Pump #1A														
Main Feed Booster Pump #1B									R	R	R	R	R	R
Main Feed Booster Pump #1C														
Fuel Oil Service Pump #1A														
Fuel Oil Service Pump #1B								L	L	L	L	L	L	L
F.W. Drain Pump #1A					R			R	R	R	R	R	R	R
Fire Pump #2					R	R								
Prairie-Masker Air Comp. #1A														
Prairie-Masker Air Comp. #1B														
Auxiliary Gland Exhaust Fan							R	R	R	R	R	R	R	R
Vent Supply Fan No. 01-84-3		L		L	L									
Vent Supply Fan No. 1-84-2		H	H		H									
Vent Exhaust Fan No. 1-85-2		L	L		L									
Vent Exhaust Fan No. 1-88-2		H		H	H									

R - RUNNING L - LOW SPEED H - HIGH SPEED I - IDLING
BLOWER SPEEDS IN KRPM

MONT[illegible]ERY POST-RAV MACHINERY LINE-UPS FOR FIRE ROOM UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	275	275A	276	277	278	285	285A	285B	287	288				
Boiler #1A	R	R	R	R	R	R	R	R	R	R				
Boiler #1B		R	R	R	R				R					
Forced Draft Blower #1A1	3.3	3.6	4.3	5.4	4.5	2.7	2.7		R	3.9				
Forced Draft Blower #1A2	3.3				4.5	2.7	2.7		R	3.8				
Forced Draft Blower #1B1		3.6	4.3	4.9	4.3				R	5.0				
Forced Draft Blower #1B2					4.5				R					
Main Feed Pump #1A	R	I	I	I	I	I	I	I	R	R				
Main Feed Pump #1B	R	R	R	R	R	R	R	R	R	R				
Main Feed Pump #1C														
Main Feed Booster Pump #1A	R								R	R				
Main Feed Booster Pump #1B	R	R	R	R	R	R	R	R	R	R				
Main Feed Booster Pump #1C						R								
Fuel Oil Service Pump #1A	L	L	L	R	R				L	L				
Fuel Oil Service Pump #1B						R	R	R						
F.W. Drain Pump #1A	R	R	R	R	R	R	R	R	R	R				
Fire Pump #2		R/		R	R				R	R				
Prairie-Masker Air Comp. #1A						R	R							
Prairie-Masker Air Comp. #1B									R					
Auxiliary Gland Exhaust Fan	R	R	R	R	R	R	R	R	R	R				
Vent Supply Fan No. 01-84-3														
Vent Supply Fan No. 1-84-2														
Vent Exhaust Fan No. 1-85-2														
Vent Exhaust Fan No. 1-88-2														

R - RUNNING L - LOW SPEED H - HIGH SPEED I - IDLING
BLOWER SPEEDS IN KRPM

MONTGOMERY POST-RAV MACHINERY LINE-UPS FOR AMR NO. 1 DOCKSIDE MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER								
	301	313	318	318A	319	386	387	388	389
SS Turbo-generator #1A						R	R	R	R
SSTG Circulating Pump #1A						R	R	R	R
SSTG Conditioning Pump #1A						R	R	R	R
SS Turbo-generator #1B									
SSTG Circulating Pump #1B		R							
SSTG Conditioning Pump #1B									
SS Turbo-generator #1C						R	R	R	
SSTG Circulating Pump #1C						R	R	R	
SSTG Conditioning Pump #1C						R	R	R	
SSTG Gland Exhaust Fan						R	R	R	
Fire Pump #1									
L.P. Air Compressor			R	R	R				
H.P. Air Compressor			R	R	R				
Fin Stabilizer #1(S)					R				
Fin Stabilizer #2(P)					R				
F.O. Transfer Pump									
ASROC Circulating Pump #1									
ASROC Circulating Pump #2			R	R	R				
SS 400 Hz. Motor Generator Set			R		R				
Vent Supply Fan #02-77-1	H			H	H	H	H	H	
Vent Exhaust Fan #02-77-2	H		H	H	H	H	H	H	

R - RUNNING L - LOW SPEED H - HIGH SPEED

MONTGOMERY POST-RAV MACHINERY LINE-UPS FOR AMR NO. 1 UNDERWAY MACHINERY TESTS

MACHINERY ITEM	RUN NUMBER													
	375	375A	376	377	378	381	382							
SS Turbo-generator #1A	R	R	R	R	R	R	R							
SSTG Circulating Pump #1A	R	R	R	R	R	R	R							
SSTG Conditioning Pump #1A	R	R	R	R	R	R	R							
SS Turbo-generator #1B														
SSTG Circulating Pump #1B														
SSTG Conditioning Pump #1B														
SS Turbo-generator #1C	R	R	R	R	R	R	R							
SSTG Circulating Pump #1C	R	R	R	R	R	R	R							
SSTG Conditioning Pump #1C	R	R	R	R	R	R	R							
SSTG Gland Exhaust Fan	R	R	R	R	R	R	R							
Fire Pump #1	R	R	R	R	R	R	R							
L.P. Air Compressor	R	R	R	R	R									
H.P. Air Compressor	R	R	R	R	R									
Fin Stabilizer #1(S)						R								
Fin Stabilizer #2(P)						R								
F.O. Transfer Pump														
ASROC Circulating Pump #1	R	R	R	R	R									
ASROC Circulating Pump #2						R	R							
SS 400 Hz. Motor Generator Set	R	R	I	R	R	R	R							
Vent Supply Fan #02-77-1	H	H	H	H	H									
Vent Exhaust Fan #02-77-2	H	H	H	H	H	L	L							

R - RUNNING L - LOW SPEED H - HIGH SPEED

MONTGOMERY POST-RAV DBA SUMMARY FOR ENGINE ROOM DOCKSIDE TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	100 QUIET BASELINE	101 VENT SYSTEM BASELINE	101A VENT SYSTEM BASELINE	102 AUXILIARIES AND VENTS	102A AUXILIARIES AND VENTS	103 LOW-SPEED BASELINE	119 FIRE PUMP #3	152 MID-SPEED NON-PROP. BASELINE	152A MID-SPEED NON-PROP. BASELINE	152B MID-SPEED NON-PROP. BASELINE	152C MID-SPEED NON-PROP. BASELINE	152D MID-SPEED NON-PROP. BASELINE	152E MID-SPEED NON-PROP. BASELINE
ML	Workbench Air Conditioner #2	1	52	82	83	79	78	79	54	80	80	80	81	80	81
ML	Log Desk by Stills	2	60	78	71	79	78	79	73	86	89	87	87	89	84
LL	Starboard MRG	3	62	75	72	82	83	83	75	88	88	89	89	90	88
ML	Port MRG	5	57	78	83	76	77	78	64	84	83	83	84	84	84
LL	Port MRG	7A	55	77	82	78	79	80	61	86	86	86	86	86	86
LL	Between F.P. and Cond.	12	63	74	71	90	76	90	89	93	93	92	90	93	94
LL	Centerline Forwared Cond. Pumps	13	65	75	72	84	78	86	83	89	89	89	89	89	90
UL	Center of MRG	14	60	77	79	76	76	75	67	85	84	85	85	85	85
ML	Forward Main Air Ejector	17	61	72	71	80	78	81	78	90	90	90	90	91	91
UL	Aft of EOS	P4	55	74	73	76	76	77	65	82		82	82	84	82
ML	By Stills - Times SQ.	10A	61	81	73	81	81	82	71	87		87	83	89	86
ML	By Air Conditioning Comp. #1	9A				84									

MONTGOMERY POST-RAV DBA SUMMARY FOR ENGINE ROOM UNDERWAY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	175 160 RPM	175A 160 R.	176 180 RPM	177 200 RPM	177A 200 RPM	178 220 RPM	181 160 RPM BASELINE	182 160 RPM ONE STILL SECURED	183 160 RPM BOTH STILLS SECURED	184 160 RPM F.P. & A.C. PLANT SECURED	186 160 RPM FIRE PUMP SECURED	189 160 RPM A.C. PLANT SECURED	
ML	Workbench A/C #2	1	33	88	87	87	86	84	83	86	86	86	86	85	
ML	Log Desk by Stills	2	89	90	89	89	86	94	89	85	85	86	86	86	
LL	Starboard MRG	3	96	94	92	94	94	93	96	94	93	94	94	94	
ML	Port MRG	5	92	91	90	91	93	94	92	90	89	90	91	91	
LL	Port MRG	7A	95	93	93	94	94	93	95	33	93	93	92	92	
LL	Between F.P. & Cond. Pumps	12	95	92	95	95	·92	97	95	95	97	93	94	95	
LL	Forward Centerline Cond. Pumps	13	92	92	93	93	93	95	92	92	92	92	92	93	
UL	Center of MRGear	14	92	94	92	92	92	96	92	92	91	92	93	92	
ML	Forward Main Air Ejector	17	91	92	93	93	94	95	91	92	92	91	92	92	
UL	Aft of EOS	P4	91	90	91	93	91	92	91						
ML	By Stills - Times SQ.	P10					87								

MONTGOMERY POST-RAV DBA SUMMARY FOR FIRE ROOM DOCKSIDE TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	200A	201 VENT SYSTEM BASELINE	202 VENTS - ONE FAN PAIR	203 VENTS - OTHER FAN PAIR	204 NON-PROPULSION BASELINE	205 FIRE PUMP #2	206 AUXILIARY GLAND EXHAUST FAN	250 ONE BOILER BASELINE	251 FDB #1B1 @ 3000 RPM	251A FDB #1B1 @ 3000 RPM	252 FDB #1B1 @ 4500 RPM	253 FDB #1B1 @ 5000 RPM	254 FDB #1B1 & 1B2 @ 3000 RPM	255 FDB #1B2 @ 4500 RPM	256 FDB #1B2 @ 5000 RPM
LL	Burner Clean Bench	58	65	73	68	71	74	67	65	84	84	84	84	84	85	84	84
LL	Between Boilers Starboard	81A	71	80	79	73	81	74	72	83	85	86	86	89	88	85	85
LL	Between PM #1B & Blr #1B	82	65	72	71	69	77	70	69	92	92	91	91	91	91	92	92
UL	Forward Main FD #1C	88	64	75	74	67	81	75	75	89	91	91	91	91	90	90	90
LL	Fire Pump #2	104	66	75	76	70	86	85	70	77	82	80	82	82	85	85	85
UL	Workbench	155	61	80	79	63	81	78	64	73	78	79	80	81	86	87	89
UL	Boilers Centerline	157	65	86	85	69	88	72	75	85	88	88	89	89	88	88	89
UL	Main FD #1A & 1B	158	60	73	72	67	76	67	68	90	91	90	90	90	91	91	90
2D	Boiler Centerline	201	59	83	83	69	85	71	76	85	89	88	91	90	89	91	92
2D	Foot of ladder to FDB rm	P202	56	83	83	60	84	64		74	80		78	80	82	82	81
UL	Between ladders port fwd	P156	63	79	79	64	80	65		73	80		78	73	81	80	81
	3-FT from by F.P						89	88									

MONTGOMERY POST-RAV DBA SUMMARY FOR FIRE ROOM UNDERWAY TESTS

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	275 160 RPM	275A 160 RPM	276 180 RPM	277 200 RPM	278 220 RPM	285 160 RPM with PM #1A	285A 160 RPM without HFBP #1C	285B 160 RPM without FDBS	287 260 RPM with PM #1B	288 160 RPM			
LL	Burner Clean Bench	58	89	87	89	89	93	91	92	89	87	87			
LL	Between Boilers Starboard	81A	91	88	91	93	97	90	90	[illegible]	89	88			
LL	Between PM #1B & Blr. #1B	82	85	86	86	88	89	86	85	83	92	85			
UL	Forward Main FD #1C	83	86	88	88	88	91	86	87	85	87	86			
LL	Fire Pump #2	104	84	83	86	88	95	83	82	[illegible]	86	86			
UL	Workbench	155			86	87	92	86	86	85	87	86			
UL	Boilers Centerline	157	90	89	90	91	95	90	90	[illegible]	89	88			
UL	Main F.D. #1A & 1B	158	91	90	91	91	92	91	91	91	91	90			
2D	Boiler Centerline	201	91	90	91	92	94	89	91	90	89	89			
2D	Foot of ladder to FDB room	P202	88	88	88	88	90	88			89	89			
UL	Between ladders port forward	P156		86	85	85	91	86			86	85			
LL	Near PM #1A	P 77						90	90	87					

MONTGOMERY POST-RAV dBA SUMMARY FOR AMR NO. 1 DOCKSIDE MACHINERY TESTS

LEVEL	MICROPHONE POSITION	MICROPHONE NUMBER	301 VENT FANS ON HIGH	313 QUIET BASELINE (SSTG CIRC PUMP #1B)	318 AIR COMPS, ASROC PUMP 2, 400HZ MG SET & VENT EXHAUST	316A SAME AS 331 W/VENT SUPPLY FAN RUNNING & 400HZ SET SECURED	319 SAME AS 318 W/VENT SUPPLY FAN & FIN STABILIZERS RUNNING	386 SSTG LOAD: #1A-240, #1C-240	387 SSTG LOAD: #1A-470, #1C-IDLING	388 SSTG LOAD: #1A-IDLING, #1C-530	309B SSTG LOAD: #1A-530
UL	Starboard Workbench	31	72	70	73	80	87	83	83	82	82
UL	Inboard TG #1A Starboard	32	76	61	75	80	86	89	89	87	90
UL	Inboard TG #1C Port	33	75	61	79	80	87	91	83	90	82
UL	Between Air Compressor Port	34	73	63	83	83	94	88	86	89	81
UL	Centerline of Aft Bulkhead	35	74		76	76	81	86	84	84	83
LL	Starboard Inboard TG #1A	36	73	70	72	76	95	90	89	83	87
LL	Port Inboard TG #1C	37	73	67	77	79	93	89	86	89	86

MONTGOMERY POST-RAV DBA SUMMARY FOR AMR NO. 1 UNDERWAY MACHINERY TEST

LEVEL	MICROPHONE LOCATION	MICROPHONE NUMBER	375 160 RPM - SSTG Load #1A-310 #1C-310	375A 160 RPM - SSTG Load #1A-330 #1C-330	376 160 RPM - SSTG Load #1A-300 #1C-300	377 200 RPM - SSTG Load #1A-290 #1C-290	378 220 RPM - SSTG Load #1A-310 #1C-310	381 Fin Stabilizers	382 Baseline for Fin Stabilizers
UL	Starboard Workbench	31	87		87	85		86	85
UL	Inboard TG #1A Stbd.	32	91	91	90	90		91	91
UL	Inboard TB #1C Port	33	90		89	90			
UL	Between Air Comp. Port	34	89	88	88	83		88	89
UL	℄ of Aft DHD	35	87		87	88			
LL	Starboard Inbd. TG #1A	36	90	89	90	90	91	90	90
LL	Port Inbd. TG #1C	37	90	90	89	90	90	90	90